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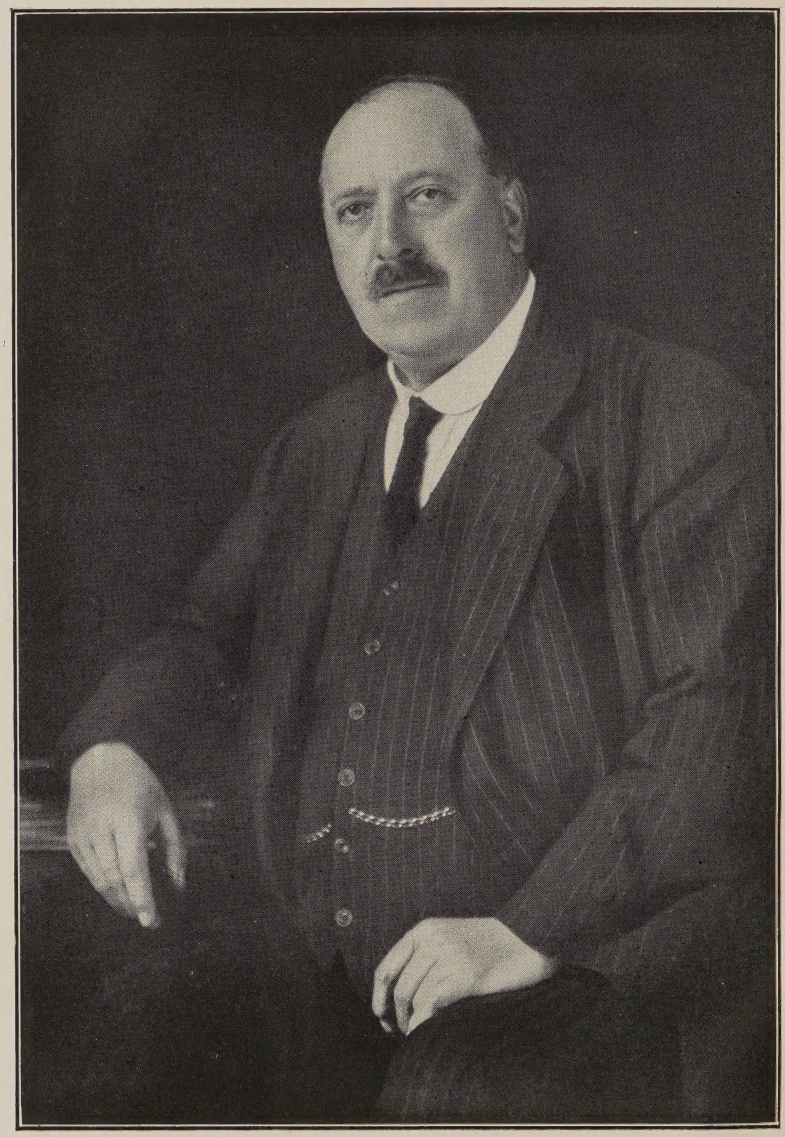

J. HOLLAND, Esq.,

President of the Ceramic Society, Session, 1923-24.

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TRANSACTIONS

OF

THE CERAMIC SOCIETY

INCLUDING

THE REFRACTORY MATERIALS SECTION.

Founded in 1900 as "The North Staffordshire Ceramic Society," and continued from 1903 to 1916 as "The English Ceramic Society."

VOLUME XXIII.—SESSION 1923-24.

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than in the green brick from which it is produced. There does not appear to be any direct relation between porosity of the brick and its mechanical strength within the limits examined.

Percentage of Fine Material (through a 90 sieve). This, in general, is about 40 per cent. although in the relatively strong brick *F* it is as low as 30 per cent.; this brick, however, has a low powder density and is made from material of high angularity, so that these two factors may counterbalance the relatively low percentage of fine material. This fine material is an important factor in the formation of a melt through which inversion of the quartz can proceed.

Percentage of Coarse Material (10, 20, 30 sieve). In the strongest bricks, this exceeds 40 per cent. Its presence is very necessary to impart strength to the brick.

Size of Largest Particles. In the strongest bricks this is of the order of 6-7 m.m. A brick with about 40 per cent. of material resting on a 30 sieve, the largest grains being about 6-7 mm., shows a well graded, uniform texture on fracture. More of this and coarser grades, as in the brick *B*, produces a weak brick.

Angularity. The figures allotted, from the grade examination, to each brick are lower for the weakest bricks. Angularity of the grains is important in promoting good packing and interlocking of the grains, and in providing the maximum properties of grain surface accessible to the action of the inversion—promoting melt.

Influence of Burning Temperature.—In order to show more clearly the effect of burning temperature on the mechanical strength of the bricks, examination of bricks made of the same material, and of the same grading, was made. These bricks were burned in works kilns to different temperatures, and the results are shown in Table VI. This table clearly shows that with increased burning temperatures, the bricks are strengthened.

TABLE VI.

EFFECT OF BURNING TEMPERATURE ON MECHANICAL STRENGTH.

Burnt to	Mechanical strength tons/in².
Cone 15	·99
16-17	1·24
20	1·39

Mechanical Strength. The crushing strength of the bricks on end, varied between 1·4 tons per sq. in to ·62 tons per sq. in. (18 to 6 tons on a 3″ brick). The strongest bricks under this test broke suddenly by shearing, but the weaker ones developed cracks in different directions and crushed in no definite way. Although silica bricks are never subjected to loads of 1 ton per sq. in. in

ordinary furnace structures, yet a high mechanical strength is important, as a strong brick is better able to resist wear and tear in handling, and retains its edges and corners. It is also important that the "clay" (or "brick batch") should be strong, so that bricks or shapes when moulded will retain their shape and not squat. In resisting this tendency to squat, the largest particles play an important part, and their size, distribution, and angularity is important.

Summary of conclusions. In conclusion, the points of practical importance in the production of a mechanically strong brick may be summarised as follows :—

(*a*) A hard, fine-grained rock, crushing into fragments of high angularity should be used.

(*b*) The grinding should be of such duration that the size of the largest particles will be of the order of 6–7 mm., with about 4 per cent. of the material retained by a 30-mesh-to-the-inch sieve. These large, angular particles give strength both to the green and the burned brick.

(*c*) If the grinding is carried out as above, the percentage of material passing a 90 mesh sieve will depend on the grain size of the rock and the strength of its bonding material. With the ganisters ordinarily used in the manufacture of silica bricks, the grain size is about ·2 mm., and when the rock is crushed so that the largest particles are 6–7 mm., rather more than 40 per cent. of the material passes through a 90 sieve. This fine material is necessary to produce compactness in the brick, and for the production of a melt which will promote the inversion of the quartz on burning.

(*d*) The bricks must be well burned. Results show that increased temperature of burning up to cone 20 increases considerably the mechanical strength of the brick.

Department of Refractory Materials,
University of Sheffield.

DISCUSSION.

Mr. C. Edwards:—I would like to ask the speaker whether in the sieving tests any attempt has been made to remove the finer fragments from the coarse by washing; because it seems to me that unless something of this sort is done, a great deal of error is likely to be introduced by the adhesion of the finer grains to the coarser ones. I am wondering whether the materials were sieved dry or washed.

Mr. P. B. Robinson:—The sieving was done entirely dry, and as each grade rested on the sieve the material was rubbed

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RULES.

(Subject to modification by recommendations from the Refractory Materials Section).

1.—The Society shall be called THE CERAMIC SOCIETY. It shall comprise a special section dealing with Refractory Materials.

2.—The object of the Society shall be the discussion of all subjects relating to the industries connected with Clay Working and Refractory Materials.

3.—Persons desirous of membership shall be proposed and seconded by two Members of the General Meeting, and they are then eligible for election at the next Council Meeting.

4.—The Society shall be governed by a President, Past-Presidents, Vice-Presidents, a Council, a Librarian, a Secretary, and a Treasurer. The President shall be elected in alternate years by the Pottery Section and by the Refractory Materials Section, and shall, upon the expiration of his year of office, become Chairman of his own Section for the ensuing year. The Office of Past-President shall be held by retiring Presidents. The Pottery Section, and the Refractory Materials Section, shall each elect three Vice-Presidents, one of whom shall retire annually, and shall not be eligible for re-election until after the lapse of one year. Other Officers shall be elected at the last General Meeting of each Session, and shall hold office until the last General Meeting of the ensuing Session, when they shall be eligible for re-election. A Chairman of Council shall be appointed by the Council.

4a.—The Council shall consist of officers, Past-Presidents, Vice-Presidents and twelve members, of whom four shall resign each year, the retiring members to be eligible for re-election.

4b.—Two additional members of the Council, one of whom will also act on the Publication Committee, shall be elected by the Federation of Pottery Manufacturers.

5.—The headquarters of the Society shall be the Central School of Science and Technology, Stoke-on-Trent.

6.—The Meetings shall be fixed from time to time as arranged by the Sectional Committees. At Stoke-on-Trent the Meetings during the Session are usually held at 7-30 p.m. on the second Monday of the month.

7.—The annual subscription shall be payable in advance, and shall be fixed from time to time by the Committee (25/- for 1923-24). Members of the Society who have paid their annual subscription receive a copy of the TRANSACTIONS free.

8.—A firm can join the Society by paying an annual subscription of two guineas. For this subscription the attendance at each meeting shall be limited to three members of the firm, and one copy of the TRANSACTIONS will be supplied free annually.

9.—New members shall pay an entrance fee of one guinea.

10.—Students may be elected to Student Memberships without paying an entrance fee. Their subscription shall be 5/-, and will entitle them to attend the meetings, but no TRANSACTIONS will be supplied. After twelve months membership, a Student can be elected to full membership without payment of entrance fee. The Council shall decide whether a person is eligible for a Student Membership.

11.—Notification of meetings shall be sent by post to each member in Great Britain with the name of the subject of the paper for discussion.

12.—In the discussions arising upon any paper, no speaker shall occupy more than ten minutes, or make more than one speech, except by the permission of the Chairman.

RULES—*Continued.*

13.—Any property of the Society lent to members must be returned within a week.

14.—Any member promising a paper and failing to keep his appointment shall himself provide a substitute.

15.—The Society shall have the prior right of publication of all papers read before it for a period of three months.

16.—Authors must send their papers to the Society before or immediately after the communication has been read. If received in time the paper may be printed in time for the meeting. The official receipt of any paper will be dated from the time it is received by the Secretary.

17.—Members may obtain one copy of each of the back numbers of the TRANSACTIONS at subscription rates, providing they are for their own personal use, and that the number in stock be over 18.

18.—Members who are three years in arrear with their subscriptions shall be informed by means of a printed notice, and if the arrears are not paid within a month their names shall be struck off the list. *New Members are put on the list of members when their subscriptions have been paid.*

19.—A member of the Society may introduce a visitor to an ordinary meeting. A visitors' book is kept to show what non-members are present, and by whom they are introduced. The names of the visitors are read out by the Chairman at the opening of the same meeting.

20.—No alteration or addition to the above Rules shall be made except notice be given in General Meeting, and passed by the ensuing General Meeting. Ten to form a quorum.

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COOKE, A. W., 40, High Street, Wolstanton .. .. .. (1918-19)
COOPER, H. F., 38, Trent Terrace, Hanley .. .. .. (1921-22)
COOPER, P. S., Partington Steel & Iron Co., Irlam, Manchester .. .. (1918-19)
COPPEE, Co., Ltd., 44, Grosvenor Place, London, S.W., 1 .. (1918-19)
CORN, E. R., Henry Richards Tile Co., Tunstall .. .. (1908-09)
CORN, E. R. G., Tolima, Trentham .. .. (1918-19)
COTTON, A., Nelson Pottery, Hanley .. .. (1912-13)
COTTON BROS., Portland Road, Longton, Stoke-on-Trent .. (1918-19)
COUPAR, A., Bassilow Farm, Fenton, Stoke-on-Trent .. (1914-15)
COX, PAUL E., Dept. of Ceramic Engineering, Iowa State College, Ames, Iowa, U.S.A. .. .. (1912-22)
CRONQUIST, G. W., Hëlsingborg, Sweden .. .. .. (1922-23)
CRONSHAW, Dr. H. B., Technical Institute, Brierley Hill, South Staffs. .. .. (1920-21)
*CROW, ROBERT, c/o Australian Porcelain Co., Ltd., 434, Law Courts Place, Melbourne, Australia .. .. (1918-19)
CULLINAN, D., Olifants Fontein, Transvaal, S. Africa .. (1921-22)
CULLINAN, R. V., c/o Box 286, Johannesburg, S. Africa .. (1913-14)
CUMING, N. F., c/o Cuming, Smith & Co., Ltd., 65, William Street, Melbourne, Australia .. .. (1921-22)
CYPLES, W. H., Trentham Road, Longton .. .. .. (1906-07)

*DALE, A. J., 14, Uttoxeter Road, Longton .. .. .. (1922-23)
DAVIDSON, J. H., M.Sc., Messrs. Wood Bros., Glass Co., Ltd., Pontefract Road, Barnsley. .. .. (1903-04)
DAVIE, C., Messrs. N. B. Allen & Co., Ltd., Hirwain, South Wales .. .. (1917-18)
DAVIS, TURNBULL & Co., 4 & 5, Prudential Buildings, Sheffield .. .. (1920-21)
DAVIS, F. W., 342, Uttoxeter Road, Longton .. .. .. (1923-24)
DAVISON, J. A., Porthill, Stoke-on-Trent .. .. .. (1905-06)
DEB, S., 45, Tangra Road, Calcutta, India .. .. .. (1918-19)
DENNIS, F. W., Holly Cottage, Ricardo Street, Dresden .. (1911-12)
DERBYSHIRE SILICA FIRE BRICK Co., Friden Station, Hartington, near Buxton .. .. (1921-21)
DERRY, B. R., Hazlehurst, Blurton Road, Fenton.. .. .. (1923-24)
DETROIT PUBLIC LIBRARY, Detroit, Mich, U.S.A. .. (1922-23)
*DEVEREUX, P. S., c/o The British Abrasive Wheel Co., Ltd., Tinsley, Sheffield .. .. (1912-13)
DUNSMUIR, G., c/o Hillview, Bonnybridge, Stirlingshire .. (1916-17)
DODD, W. H., 147, Bucknall New Road, Hanley, Stoke-on-Trent (1909-10)
DOLBY, W. J., 24, Whitfield Avenue, Newcastle, Staffs. .. (1920-21)
DOUGALL, JAMES & SONS, Ltd., Firebrick Works, Bonnybridge, Stirlingshire .. .. (1916-17)
DOUGLAS FIREBRICK Co., Ltd., Kilwinning .. .. (1916-17)
DRESSLER TUNNEL OVENS, Ltd., Holmthorpe, Redhill, Surrey .. .. (1916-17)
DRESSLER, PHILIP, 1543, East Boulevard, Cleveland, Ohio, U.S.A. .. .. (1918-19)
*DUFFIELD, F., L, The Derbyshire Basic Co., Ltd., 99 Pinstone Street, Sheffield .. .. (1921-22)
DUNN, F. T., Messrs. The Henry Richards Tile Co., Tunstall, Stoke-on-Trent .. .. (1906-07)
*DUNN, J. T., D.Sc., F.I.C., Public Analysts' Laboratory, 10, Dean Street, Newcastle-on-Tyne .. .. .. (1916-17)
DYSON, J. & J., Ltd., Griffs Fireclay Works, Stannington, nr. Sheffield .. .. (1922-23)

EARDLEY, DONALD, 21, Cobden Street, Dresden, Stoke-on-Trent .. .. (1920-21)
EDINBURGH & LEITH FLINT GLASS WOKKS, Norton Park, Edinburgh .. .. (1916-17)
EDWARDS, A. O., c/o The Yorkshire Refractories Co., Ltd., 27, Waterdale, Doncaster .. .. (1917-18)
EDWARDS, J. C., Terra Cotta Works, Ruabon .. .. (1921-22)
EDWARDS, W. H., Park Lane, Fenton, Stoke-on-Trent .. (1921-22)
EDWARDS, C., Rosslea, 4, Aspley Road, Wandsworth, London, S.W.18 .. .. (1914-15)
EGLINTON MAGNESITE BRICK Co., Ltd., Dundyvan Brick Works, Coatbridge .. .. (1917-18)
ELLAND FIRECLAY Co., Ltd., Calder Fireclay Works, Elland (1916-17)
ELLIS, THOS., Penwyllt, near Neath .. .. (1916-17)
ELEY, ERNEST E., 15, Lord Street, Basford, Stoke-on-Trent (1920-21)
*EMERY, W., 7, Catherine Street, May Bank, Staffs. .. .. (1902-03)
EMERY, W. L., Kensington Pottery Ltd., Statham St., Hanley (1924-25)
ENDELL, K. Dr., Berlin Steglitz, Breitestrasse 3, Germany.. (1920-21)
ETCHELLS, H., 56, Westwood Road, Sheffield.. .. .. (1917-18)
EVERITT, CHARLES KINGSTON, c/o Edgar Allen & Co., Ltd., Imperial Steel Works, Sheffield .. .. .. (1916-17)

FAILL, JAMES, 146, West Regent Street, Glasgow .. .. (1916-17)
FARNLEY IRON Co., Ltd., Farnley, near Leeds .. .. (1916-17)
FEARNSIDES, W. G., 11, Ranmoor Crescent, Sheffield .. (1916-17)

FERGUSON, R. F., Box 74, Bolivar, Pa., U.S.A... .. .. (1923-24)
FERN, E. R., School of Art, Bombay .. .. (1906-07)
*FIELDING, A., Devon Pottery, Stoke-on-Trent .. .. (1902-03)
FIELDING, R., Devon Pottery, Stoke-on-Trent .. .. (1906-07)
FINN, R., 2, Eaton Street, Hanley .. .. (1920-21)
FOLEY, F. D., Loch Lomond Road, St. John's, N.B., Canada (1917-18)
FORD, SAMUEL & Co., Lincoln Pottery, Burslem .. .. (1921-22)
FOSTER, HENRY & Co. Ltd,, Backworth, Newcastle-on-Tyne (1916-17)
*FOSTER, J. E., 48, Gilman Street, Hanley .. .. .. (1909-10)
*FOX, W. G., 44, Riseley Road, Hartshill, Stoke-on-Trent .. (1912-13)
FOXWELL, G. E., 62, Albany Mansions, Albert Bridge Road, S.W.11 .. .. (1916-17)
FREEMAN, Dr. LUDFORD, Abbotsthorpe, Carnarvon Road, Redland, Bristol .. .. (1914-15)
FULPER, W. H., c/o The Fulper Pottery Co., Flemington, N. J., U.S.A. .. .. (1910-11)

GARDNER, W. J., c/o The Meltham Silica Brick Co., Ltd., Meltham, near Huddersfield.. .. .. (1916-17)
GARDNER, W. T., F.C.S., 14, Beechwood Avenue, Kew Gardens, London, S.W. .. .. (1918-19)
GATENSBURY, H. R., Atlas Foundry, Victoria Road, Hanley (1913-14)
GELSTHARP, F., Director of Research, Pittsburgh Plate Glass Co., Creighton, Pa. .. .. (1911-12)
GIBBONS, Ltd., Dibdale Works, Dudley .. .. .. (1916-17)
GIBBS, A. E., 1012, Widoner Buildings, Philadelphia, Pa., U.S.A. .. .. (1918-19)
GIBSON, W. F., 125 Tweedale Street, Rochdale .. .. (1923-24)
GILL, W. R., Cleveland Villa, Castleford, Yorkshire.. .. (1909-10)
GILL, G. M., 119, Victoria Street, London, S.W.1... .. .. (1922-23)
GIMSON, J. F., 69, Fountain Square, Fenton, Stoke-on-Trent (1920-21)
GIPP, H. W., General Manger, Electrolytic Zinc Co. of Australasia, Box, A.A., Hobart, Tasmania .. .. .. (1918-19)
GLENBOIG UNION FIRECLAY Co., Ltd., Glenboig, Scotland (1916-17)
GLEAVES, E., Alsager House, Marsh Avenue, Wolstanton, Stoke-on-Trent .. .. (1920-21)
GLOVER, SAMUEL, F.R.M.S., Olive Mount, St. Anns, St. Helens .. .. (1916-17)
GODDARD, J. V., Trentham .. .. (1905-06)
GODDARD, A. H., c/o Messrs. G. L. Ashworth Bros., Ltd., Hanley .. .. (1918-19)
GOODWIN, F. T. H., Hollydean, Park Avenue, Longton .. (1910-11)
GOODWIN, W. E., Watcombe House, 225, Waterloo Road, Burslem .. .. (1902-03)
GOODWIN, JOHN, Foley Works, Fenton, Stoke-on-Trent .. (1920-21)
GOSLING, JAS., Atlas Foundry, Victoria Road, Hanley .. (1913-14)
GOSS, W. H., Falcon Pottery, Stoke .. .. (1914-15)
GRAHAM, J. W., Ashley Villa, Lancaster Av., Newcastle Staffs. .. .. (1914-15)
GRAY, A. E., Glebe Works, Mayer Street, Hanley .. .. (1917-18)
GRAYSON, LOWOOD, J. & Co., Ltd., Deepcar, near Sheffield (1916-17)
GRAY, J., Auldhaven, Milngavie .. .. (1918-19)
GREAVES-WALKER, A. F., Box 1122, Pittsburgh, Pa, U.S.A. .. .. (1920-21)
GREEN, A. T., 579, High Lane, Burslem, Stoke-on-Trent .. (1917-18)
GREEN, G. D., Hobbergate, Brampton, Newcastle .. .. (1921-22)
GREEN, J. C., 49, Bromley Road, Kingswinsford, Staffs. .. (1911-12)
*GREEN, S. A., Brampton Hill, Newcastle, Staffs. .. .. (1905-06)
GREGORY, C., Newfield, Willington, Co. Durham .. .. (1916-17)
GREGORY, J. G. & SON, Friars Street, Newcastle, Staffs .. (1921-22)

GREGORY, REDDISH & Co., Ltd., Silica & Firebrick Works, Deepcar, near Sheffield .. .. (1916-17)
GRICE, E., 21, Station Road, Meir, Longton, Staffs. .. .. (1913-14)
GRIMWADE, C. D., Fairlands, Trent Vale, Stoke-on-Trent .. (1918-19)
GRINDLEY, W. H., Woodland Pottery, Tunstall .. .. (1906-07)
GROCOTT, W., 75, Shenstone Road, Edgbaston, Birmingham (1918-19)

HAGUE, A. P., c/o Cammell Laird & Co., Ltd., Cyclops Steel and Iron Works, Sheffield .. .. (1920-21)
HALL, HY., The Bungalow, Botteslow, Hanley.. .. .. (1912-13)
HALL, J. & Co., Stourbridge .. .. (1916-17)
HALLIDAY, H., 25, Victoria Street, Westminster, London, S.W. (1923-24)
HAMILTON, J., Ideal Pottery, Trenton Potteries Co., Trenton, U.S.A. .. .. (1906-07)
HAMILTON, WILLIAM, 41, St. Vincent Place, Glasgow, C1. .. (1917-18)
HAMMOND, PERCY, Newbridge House, Bollington, Macclesfield .. .. (1916-17)
HAMMOND, WILLIAM, Jevington, Bollington, Macclesfield (1916-17)
HAMPTON, T. E., Eastwood Marl Works, Hanley .. .. (1908-09)
HANCOCK, E. A., Kepax, Worcester .. .. (1916-17)
*HANCOCK, W. C., B.A., F.I.C., 60, Greek Street, Soho Square, London, W.1 .. .. (1917-18)
HARBORD, F. W., 16, Victoria Street, London, S.W. .. (1916-17)
HARDING, F. W., 6, Hassell Street, Hanley .. .. .. (1921-22)
HARRIS, GUY, Messrs. Bullers, Ltd., Milton .. .. .. (1922-23)
HARRISON, A. C. Bath Street, Hanley .. .. .. (1910-11)
HARRIMAN, WM., & Co., Ltd., 51, Westgate Road, Newcastle-on-Tyne .. .. (1917-18)
HARRINGTON, T. H., The Square, Ironbridge, Salop .. (1913-14)
HARRINGTON, A., Tower Hill Farm, Mow Cop, Stoke-on-Trent (1923-24)
HARRISON, T. S., May Place, Newcastle, Staffs. .. .. (1921-22)
HARRISON, J. H., Godolphin House, Wolstanton, Stoke-on-Trent .. .. (1923-24)
HARTLEY, H. L., Castleford Pottery, Castleford, Yorks .. (1917-18)
HARTMANN, M. L., The Carborundum Co. Niagara Falls, N.Y., U.S.A. .. .. (1921-22)
HARVEY, G., 78, Baskerville Road, Hanley .. .. .. (1921-22)
HASSALL, W., Tresco House, Woodville, Burton-on-Trent (1920-21)
HAUNCHWOOD BRICK & TILE Co., Ltd., Nuneaton .. (1921-22)
HAWLEY, E., Woodland Cottage, Blurton, Staffs. .. .. (1914-15)
HAWLEY, ERNEST, c/o Messrs. Hawley & Jackson, Longton (1913-14)
HAWLEY, W. S., Fairmont, Sunny Bank Road, Newcastle, Staffs. .. .. (1908-09)
*HEATH, A., 71, Park Road, Hanley .. .. (1900-01)
HEATH, B. C., St. Edmunds Avenue, Porthill, Staffs. .. .. (1921-22)
HEATH, C. H., High Street, Woodville, near Burton-on-Trent (1915-16)
HEATH, F., 35, Harpfield Road, Trent Vale, Stoke-on-Trent .. (1923-24)
HEATON, WM., Ravenhead Brick Co., Upholland, near Wigan (1917-18)
HENDERSON, H. B., 1538, N. High St., Columbus, Ohio, U.S.A. .. .. (1911-12)
HENDERSON, J. D., c/o The Anglo-Greek Magnesite Co., 24, Finsbury Square, London, E.C. .. .. (1917-18)
HEPWORTH IRON Co., Ltd., Hazlehead, near Sheffield .. (1916-17)
HEYS, F. R., Hydro., Kilmacolm, Scotland .. .. .. (1921-22)
HEWITT, A. E., Easedale, Trentham, Stoke-on-Trent .. (1912-13)
HEWITT, F. G., 6, Boughey Street, Stoke-on-Trent .. .. (1918-19)
HIGGINS, F. W., Carborundum Co., Ltd., Trafford Park, Manchester .. .. (1918-19)
HILL, WESTLAKE & Co., Ltd., 8 Gloucester Sq., Southampton (1920-21)
HIMLEY FIRE & RED BRICK Co., Ltd., near Dudley .. (1916-17)

HINCHLIFFE, HERBERT, Bullhouse Colliery, Penistone, Sheffield .. .. (1917-18)
*HIND, S. R., 48, Colclough Road, Meir, Stoke-on-Trent .. (1918-19)
HITCHEN, W., 12, Denby Lane, Heaton Chapel, Stockport .. (1923-24)
HOBBS, W. L., Dyserth, Flintshire .. .. (1916-17)
HODSON, G. A., c/o The Hathern Station Brick & Terra-Cotta Co., Ltd., Loughborough .. .. (1908-09)
HOLCROFT, N. P., Holmlea, Market Street, Milton, Stoke-on-Trent .. .. (1923-24)
*HOLDCROFT, A. D., Bradwell Lane, Wolstanton .. .. (1902-03)
*HOLDCROFT, J. P., Bradwell Lane, Wolstanton .. .. (1902-03)
HOLDCROFT, L., Stockton Brook, Stoke-on-Trent .. .. (1923-24)
HOPE, H., Liverton, nr. Newton Abbot, Devon.. .. .. (1907-09)
HOPE, G. F. W., The Dingle, Fingringhoe, Colchester .. .. (1920-21)
*HOULDSWORTH, H. S., 10, Rydal Terrace, Heckmondwicke, Yorks .. .. (1921-22)
HOWELL, W. E., 41, Sneyd Terrace, Burslem .. .. .. (1915-16)
HOWLETT S. J., 23, Broom Street, Hanley .. .. .. (1918-19)
HOWIE, F. C., Hurlford Fireclay Works, Kilmarnock .. (1916-17)
HOWSON, R. G., c/o Messrs. G. Howson & Sons, Limited, Hanley .. .. (1907-08)
HUBBARD, A. E., 64, Psalter Lane, Sharrow, Sheffield .. .. (1922-23)
HUGHES, F. S., Opal China Works, Fenton, Staffs. .. .. (1909-10)
HUGILL, W., B. Met. 5, Falmouth Road, Abbeydale, Sheffield (1923-24)
HULL, R., Junr., Wellcroft, Caverswall Lane, Blythe Bridge (1923-24)
HUNT, PERCY, Whiteley Cottage, Marehay, Derbyshire .. (1921-22)
HURLL, Ltd., P. & M., 144, West Regent Street, Glasgow .. (1917-18)
HUTTON, R. S., D.Sc., Castle Hill, High Wycombe, Bucks .. (1916-17)

IVERS, B., Marikuppam, Kola Gold Fields, South India .. (1922-23)

JACKSON, CHARLES E., Warwick China Co., Wheeling, Pa., U.S.A. .. .. (1922-23)
JACKSON, E. W., F.I.C., Godrevy, Saltburn-by-the-Sea .. (1918-19)
JACOBSEN, CARL, Malmegade 7, Copenhagen, Denmark
JEFFREY, Dr. J. A., c/o Champion Porcelain Co., Detroit, Mich., U.S.A. .. .. (1917-18
JEPPSON, G. N., 41, Burncoat Street, Worcester, Mass., U.S.A. .. .. (1912-13)
JOHNSON, A., 16, Garden Village, Weston Coyney .. .. (1922-23)
JOHNSON, A. S., c/o Messrs. Alfred Meakin, Ltd., Tunstall.. (1909-10)
JOHNSON, S. Ltd., Brittania Pottery, Burslem, Stoke-on-Trent .. .. (1920-21)
JOHNSTON, T. B., Park House, Eastfield Park, Weston-Super-Mare .. .. (1918-19)
JOHNSON, E., c/o Messrs. W. Boulton, Ltd., Navigation Rd., Burslem .. .. (1909-10)
JOHNSON, H., Tile Manufacturer, Highgate Tile Works, Tunstall .. .. (1906-07)
JOHNSON, J., Talke and Alsager Road, Alsager .. .. (1912-13)
JOHNSON, R. L., Oulton Rocks, Stone, Staffs... .. .. (1912-13)
JOHNSON, W. P., B.Sc., Foundry Lane, Wallheath, near Dudley .. .. (1910-11)
JOHNSON, H. C., Clayton Hall, Newcastle, Staffs. .. .. (1923-24)
JONES, A. B., Junr., Grafton Works, Longton .. .. .. (1914-15)
JONES, A. G., Lynton, Trentham, Staffs. .. .. .. (1909-10)
JONES, A. G. H., Heath House, Uttoxeter .. .. .. (1905-06)
JONES, CHARLES, Heatherfield, Bwlchgwyn, near Wrexham (1916-17)
JONES, CHESTER H., 1570, Old Colony Buildings, Chicago, U.S.A. .. .. (1921-22)

JONES, GEO., & SONS, Ltd., Crescent Pottery, Stoke-on-Trent (1921-22)
JONES, L. Southwood, c/o Messrs. Southwood, Jones & Co., Danycraig Works, Risca, Monmouth .. .. .. (1916-17)
JONES, N. L., c/o J. & G. Meakin, Ltd., Hanley .. .. (1914-15)
*JONES, R. H. H., Riversdale, Keyberry Road, Newton Abbot (1900-01)
JONES, Sir W. J. 17, Victoria Street, Westminster, S.W.,1 .. (1916-17)
JONES, W. R., "Wagon and Horses" Hotel, Wallheath, nr. Dudley (1921-22)
JONES, W. R., 3, Lenches Bridge, Pensnett, near Dudley .. (1921-22)
JONES, W. R. D., University College, Cardiff .. .. .. (1921-22)
JONES, AUSTIN, c/o Messrs. Edwards & Jones, Engineers, Longton, Stoke-on-Trent .. .. (1922-23)

KANHÄUSER, Dr. FRANZ, Chodor u Karl, Varu, Czechoslovakia .. .. (1922-23)
KEELING, F. A., c/o Messrs. Keeling & Walker, Stoke-on-Trent .. .. (1906-07)
KEELING, J., c/o Keeling & Co., Dalehall, Burslem .. .. (1906-07)
KEELING, G. A., Brown Edge Road, Stockton Brook, Stoke-on-Trent .. .. (1918-19)
KENT, W. F., 72, Leonard Street, Burslem .. .. .. (1903-04)
KENT, W., c/o. Messrs. Taylor Tunnicliff & Co., Hanley, Stoke-on-Trent .. .. (1920-21)
KIRKLAND, H. S., Albion Pottery, Etruria, Stoke-on-Trent (1906-07)
KLEIN, CARL, A., 4, Brimsdown Av., Enfield Highway, Middlesex .. .. (1915-16)
KNIGHT, W. C., Westholme, Barnfields, Penkhull, Stoke-on-Trent.. .. .. (1908-09)
KOPPERS, Dr. H., Malthestrasse 29, Essen .. .. .. (1923-24)
KREHBIEL, J. F., 168E, Lake view Avenue, Columbus, Ohio, U.S.A. .. .. (1917-18)

LADREDA, F. F., Capitan de Artilleria San Claudio (Oviedo), Spain .. .. (1922-23)
LANCASTER, E., Lyndhurst, Trentham .. .. .. (1914-15)
LAPORTE, B., Ltd., Soap and Chemical Works, Luton, Beds... (1922-23)
LEACH, C. A., Padeswood, Weston Coyney, Stoke-on-Trent.. (1922-23)
LEATHER, J. P., Pendle, 6, Sollershott East, Letchworth, Herts. (1916-17)
LEEDS FIRECLAY Co., Ltd., Wortley, Leeds.. .. .. (1916-17)
*LEESE, A., 81, Vivian Road, Fenton, Staffs. .. .. .. (1900-01)
LESSING, R., PhD., The Laboratory, Southampton House, 317 High Holborn, London .. .. (1910-11)
LEWIS, E. H., The Green, Wishaw, Scotland .. .. .. (1917-18)
LILLESHALL (The) Co., Ltd., Priors Lee Hall, Shifnal, Salop (1916-17)
LILLIBRIDGE, H. D., c/o American Encaustic Tiling Co., Ltd. Zanesville, Ohio, U.S.A. .. .. (1916-17)
LINDOP, R. C., 41, Grove Road, Fenton.. .. .. .. (1913-14)
LINSTRUM, T., Peacocks Bdg., 23, Park Row, Leeds.. .. (1917-18)
LLOYD, HORACE, Messrs. N. B. Allen & Co., Ltd., Hirwain, South Wales .. .. (1917-18)
LLOYD, W. J., Rothesay, King's Avenue, Wolstanton .. (1915-16)
LLOYD, T. H., c/o The Pure Bone Phosphate Co., 27, Kirkgate, Newark .. .. (1918-19)
LOCKHART, D. B., Victoria Pottery, Pollokshaws, Glasgow (1918-19)
LOUDON, JOHN, Loudon & Russell, Ltd., Allanton Fireclay Works, Newmains, Scotland.. .. .. (1917-18)
LOVATT, L. D., 79, Festing Street, Hanley .. .. .. (1916-17)
LOXTON, N. G., Leeds Fireclay Co., Burmantofts Works, Leeds (1918-19)
LUCAS, W. T., The Limes, Alsager .. .. (1921-22)
LYSAGHT, J., Ltd., Normanby Park Works, Scunthorpe, Lincs. (1918-19)

MACHIN, C. W., 65, Trentham Road, Longton .. .. (1914-15)

McGAVIN, WILLIAM, c/o The Priestman Collieries, Ltd., Whinfield, Rowlands Gill, nr. Newcastle-on-Tyne.. .. (1923-24)
Mc KINLAY, PARKER, "Benhar," Otago, New Zealand .. (1921-22)
MACLEOD, W. A., 17, Gayton Road, Harrow-on-the-Hill .. (1923-24)
MacNEAL, C., Lloyds Bank Chambers, Fenton, Staffs. .. .. (1910-11)
MacWHIRTER, J., Elsinore, Milngavie, Scotland .. .. (1917-18)
McCORMICK, J., Dock Office, Hull, Yorks. .. .. .. (1917-18)
McCANCE, Dr. A., Westview, Uddingston .. .. .. (1918-19)
McDOWELL, J. S., 1800, Farmers Bank Buildings, Pittsburgh, U.S.A. .. .. (1918-19)
McNEIL, G., 181, Main Street, Bellshill, Lanarkshire .. .. (1918-19)
MALKIN, S., c/o The Malkin Tile Works Co., Burslem .. (1905-06)
MALKIN, W. F., Dalehall Mill, Burslem .. .. .. (1914-15)
MALKIN, J. R., Penryn, Grosvenor Place, Wolstanton .. (1918-19)
MANSFIELD, F., 9, Red Cross Street, Liverpool .. .. (1918-19)
MARLOW, J. H., 19, The Villas, Stoke-on-Trent .. .. (1916-17)
MARSHALL, F. J., 48, Mayer Street, Hanley .. .. .. (1911-12)
*MARTIN, GEOFFREY Dr., Rosherville Court, Burch Road, Gravesend .. .. (1921-22)
MASON, ADAM & SONS, Ltd., Horwich, Lancashire.. .. (1916-17)
MASSACHUSETTS INSTITUTION OF TECHNOLOGY, Massachusetts Avenue, Cambridge Mass., U.S.A. .. .. (1922-23)
*MAYER, E. W. T., 11, Westwood Road, Wolstanton.. .. (1914-15)
MEAKIN, J. & G., Ltd., Eagle Pottery, Hanley, Stoke-on-Trent (1918-19)
MEIR, J., The Barn, Grosvenor Place, Wolstanton .. .. (1911-12)
MELLOR, BERT, 16, Pottery Road, Bovey Tracey, Devon .. (1924-25)
*MELLOR, J. W., D.Sc., Sandon House, Regent St., Stoke-on-Trent .. .. (1904-05)
MELLOR, G. & Co., Ltd., Etruria Vale Mills, Stoke-on-Trent .. (1923-24)
MEREDITH, J., New Villas, Shirley Road, Hanley .. .. (1911-12)
METHVEN DAVID & SONS, Kirkcaldy Pottery, Kirkcaldy .. (1922-23)
MICHELSEN, H. C., 33, Vestergade, Copenhagen .. .. (1921-22)
MICHIE, A. C.,12, Akenside Hill, Newcastle-on-Tyne .. (1910-11)
MIDDLETON FIRECLAY WORKS, Leeds .. .. .. (1916-17)
MITCHELL, JOHN, c/o A. Y. Dinas Silica Brick Co., Ltd., 142, Queen Street, Glasgow .. .. (1916-17)
MITCHELL, J. S., Hyland, Hargate Drive, Hale, Manchester (1917-18)
MOBBERLEY, J. A., Firebrick Manufacturer, Stourbridge .. (1923-24)
MOKIJI, ICBIJE, c/o. Kurasaki Togio Co., Kurasaki machi, Fukuokaken, Japan. .. .. (1922-23)
MOLLER, C. A., Vestergade, 33, Copenhagen, Denmark .. (1921-22)
MOMOKI, S., c/o Toyo Tokio Kwaisha Ltd., Shinozaki, nr. Kokura City, Japan .. .. (1916-17)
MONTGOMERY, ROBERT J., c/o Bausch & Lomb Optical Co., Co., Rochester, N.Y., U.S.A .. .. (1918-19)
MONTGOMERY, ALLAN W., 58, York Street, Glasgow .. (1918-19)
*MOORE, B., Wolfe Street, Stoke-on-Trent .. .. .. (1900-01)
*MOORE, BERNARD, J., The Gables, Bromley Hough, Penkhull, Stoke-on-Trent .. .. (1913-14)
MOORE, C. H., 244, Fulwood Road, Sheffield .. .. (1917-18)
MOORE, CHRISTOPHER E,, The Hurst, Hagley, Stourbridge (1921-22)
MOORSHEAD, T.C., 40-43, Norfolk St., Strand, London, W.C.2. (1921-22)
MORFEY, H. A., The Shelton Iron Steel & Coal Co., Ltd., Stoke-on-Trent .. .. (1923-24)
MORETON, WILLIAM P , c/o Messrs. Thos. Forrester & Sons, Ltd., Phœnix Works, Longton, Stoke-on-Trent .. .. (1921-22)
MORTON, JOSEPH, Ltd., Cinder Hill Fireclay Works, Halifax, Yorks. .. .. (1917-18)
MORRALL, F., 49, Kensington Road, Oakhill, Stoke-on-Trent (1917-18)
MOSS, G. H., 47, Heron Street, Fenton, Stoke-on-Trent .. (1920-21)

MOTTRAM, GEO. WM., Trevelyan Blgs., 52, Corporation Street, Manchester .. .. (1923-24)
MOULTON, D.A., Iowa State College, Dept. of Ceramic Engineering, Ames; Iowa, U.S.A. .. .. (1918-19)
MOURITZEN, C. F., Calyx Paint Works, Lord Street, Perth, Western Australia .. .. (1920-21)
MYERS, E. M., The Indian Iron & Steel Co., Ltd., Hirapur, Works, Asansol, E.I.R., Bengal, India .. .. .. (1921-22)
MYOTT, A., c/o Messrs. Myott, Son & Co., Cobridge, Burslem (1904-05)

NAKATSUJI, MASANSBU, Jamo Jasto, nr. Osaka, Japan .. (1923-24)
NEGUS, W., 36, Bloomsbury Square, London, W.C. 1 .. (1918-19)
NEWBY, F. B., c/o Malkin Tile Works, Burslem, Staffs .. (1917-18)
NEWMAN, H. S., Sunnyside, Oxford Road, Basford Park, Stoke-on-Trent .. .. (1917-18)
NEWSOM, F. S., c/o Pountney & Co., Ltd., Fishponds, Bristol.. (1922-23)
NEW YORK PUBLIC LIBRARY, 476, Fifth Avenue, New York, U.S.A. .. .. (1921-22)
NICHOLSON, E. D., Park Issa, Oswestry .. .. .. (1918-19)
NIXON, WM., Mayfield, Weston Coyney, Stoke-on-Trent .. (1916-17)
NOBLE, E., Birch House, Worksop .. .. (1917-18)

OATES & GREEN, Ltd., Halifax, Yorks. .. .. .. (1916-17)
OAKES, W. c/o. Sand, Glass & Foundry Materials (Amalgamated) Ltd., 27, Waterdale, Doncaster .. .. .. (1920-21)
*ODELBERG, A.S.W., Gustafsberg Pottery, Gustafsberg, Sweden (1904-05)
OKURA, K., 22, Ipponmattsu, Azab, Tokyo, Japan .. .. (1915-16)
*OLSEN, B., The Villas, Stockton Brook, Stoke-on-Trent .. (1900-01)
*ORMANDY, W. R., D.Sc., 18, Belsize Grove, Belsize Park, N.W. 3. .. .. (1917-18)
OUGHTIBRIDGE SILICA FIREBRICK WORKS, The Oughtibridge, Sheffield .. .. (1916-17)

*PAGE, E. P., 123, Abbey Foregate, Shrewsbury .. .. (1904-05)
PAINE, J. W. R., Calder Fireclay Co., Coatbridge .. .. (1918-19)
PARKER, W. B., F.I.C., 3, Murray Road, Rugby .. .. (1918-19)
PARKINSON & SPENCER, Ambler Thorn Fireclay Works, Halifax .. .. (1916-17)
PARMELEE, C. W., Professor of Ceramic Engineering, University of Illinois, Urbana, Illinois, U.S.A. .. .. (1906-07)
PASS, R. H., West Rising, Onondaga Pottery Co., Syracuse, N.Y., U.S.A. .. .. (1920-21)
PEARSALL, W. H., c/o Mobberley & Bayley, Stourbridge .. (1916-17)
PEARSON, E. J. & J., Ltd., Fireclay Works, Stourbridge .. (1916-17)
PEARSON & Co., The Potteries, Whittington Moor near Chesterfield .... (1918-19)
PEASE & PARTNER, Ltd., Darlington .. .. (1923-24)
PEREGRINE, C. R., C/o Macbeth-Evans Glass Company, Marion, Indiana, U.S.A. .. .. (1917-18)
PERRY, G. H. PEARSON, Portland House, Pedmore, nr. Stourbridge .. .. (1916-17)
*PERRY, T., 247, Campbell Road, Stoke-on-Trent .. .. (1910-11)
PICKFORD, HOLLAND & Co., Ltd., Eclipse Ganister Works, Attercliffe, Sheffield .. .. (1916-17)
PICKFORD, R. J., Thornlea, Carmel Road, Darlington .. (1917-18)
PIKE, L. G., Wareham, Dorset .. .. (1912-13)
PILLAI, D. S., 56, West Street, Penkhull .. .. .. (1923-24)
PINHEIRO DA SILVA, ISRAEL CARTHE, Minas Gerais, Brazil, South America .. .. (1920-21)
PITCAIRN, G., Fabrica-de-Loza, San Juan de Aznal-farache, Sevilla, Spain .. .. (1916-17)

PLANT, F., Stone Road, Longton .. .. (1912-13)
*PLANT, H. J., Rostherne, Park Avenue, Longton, Stoke-on-Trent .. .. (1902-03)
PLANT, J., Melbourne House, Stone .. .. (1912-13)
PODMORE, A. J., Consall Hall, Consall, Stoke-on-Trent .. (1916-17)
PODMORE, WM., Consall Hall, Consall, Stoke-on-Trent .. (1913-14)
POLGREAN, J. H., 183, Leek New Road, Burslem .. .. (1921-22)
POOLE, THOS., Cobden Works, Longton .. .. .. (1915-16)
POOLE, HORACE, 96, Chaplin Road, Longton .. .. (1916-17)
POTTERY MANAGERS ASSOCIATION, A. E. Holdcroft, Sec., Woodland Avenue, High Lane, Burslem .. .. .. (1922-23)
POUNTNEY & Co., Ltd., The Bristol Pottery, Fishponds, near Bristol .. .. (1918-19)
POWELL, W. H., 41, Plymouth Street, Monteclair, New Jersey, U.S.A. .. .. (1908-09)
PRESTON, D., 35, High Street, Bucknall, Stoke-on-Trent .. (1916-17)
PRICE, G., Clifton, Milehouse Lane, Wolstanton, Staffs. .. (1908-09)
PRICE, J. T. & Co., Ltd., Stourbridge .. .. (1916-17)
PRICE, S. H., "Lag-na-ha," Porthill, Stoke-on-Trent .. .. (1912-13)
PRYOR, E. A. COAD, The National Physical Laboratory, Teddington, Middlesex .. .. (1917-18)

*RAMSDEN, C. E., Foley Colour Works, Fenton, Stoke-on-Trent (1902-03)
RAMSAY, A., Mount Savage, Md., U.S.A. .. .. .. (1908-09)
RANN, R. C., 17, Victoria Street, Westminister, London, S.W. 1. .. .. (1918-19)
REDFERN & DRAKEFORD, Balmoral Works, Normacot, Stoke-on-Trent .. .. (1918-19)
REED, G. H., 53, Beverley Road, Chorley New Road, Bolton, Lancs. .. .. (1921-22)
*REES, WALTER, J., Department of Refractory Materials, The University, Sheffield .. .. (1916-17)
RHEAD, F. H., Director, Research Dept., American Encaustic Tiling Co., Zanesville, Ohio, U.S.A. .. .. (1920-21)
RHEAD, T. F. E., 10, Malvern Road, Acocks Green, Birm'ham (1921-22)
REYNOLDS, G., Tachbroke House, Normacot.. .. .. (1903-04)
*RICHARDSON, A. G., "Linden," Oakville Avenue, High Lane, Burslem .. .. (1900-01)
RICHARDSON, GEO., 140, Pinnox Street, Tunstall
RICHARDSON, W. D., The Ceramic Engineering Co., 1466, Michigan Avenue, Columbus, Ohio, U.S.A... .. .. (1906-07)
RIDGE, H. M., 2, Great Winchester Street, E.C. 2 .. .. (1917-18)
RIDGWAY, B. Bedford Works, Hanley .. .. (1913-14)
RIDGWAY, F. J., H. Aynsley & Co., Commerce Street, Longton, Stoke-on-Trent .. .. (1921-22)
RIES, H., Cornell University, Ithaca, New York .. .. (1911-12)
RIGBY, A., St. Anthony's Drive, Newcastle, Staffs. .. (1920-21)
RIGBY, J. H., Buccleuch Road, Longton .. .. .. (1921-22)
RILEY, HAROLD E., Tresco, St., Austell .. .. .. (1917-18)
ROBERTS, J. G., c/o Messrs. Shanks & Co., Barrhead, N.B (1904-05)
ROBERTS & MAGINNIS, Ltd., Trevor, Ruabon, N. Wales .. (1921-22)
ROBERTSON, N. L., (Capt.) M.C.; B.Sc., 17, Riddrie Knowes, Glasgow .. .. (1921-22)
ROBINSON, H. T., China Works, Shelton, Stoke-on-Trent .. (1917-18)
ROBINSON, P. B., 20, Aynsley Terrace, Consett, Co. Durham.. (1922-23)
ROBERTSON, N. L., Dregham, Tanfield Road, Blowers Green, Dudley .. .. (1922-23)
ROSS, DONALD W., The Findlay Clay Pot Co., Washington, Pa, U.S.A. .. .. (1917-18)
ROYCE, Miss F. A., 24, McKillop Street, Geelong, Victoria .. (1922-23)

ROWLAND, B. R. & Co., Ltd., Climax Works, Reddish, nr. Stockport .. .. (1923-24)
ROWLEY, T. H., 63, Gilman Street, Hanley .. .. .. (1921-22)
*RUSSELL, FRANK, Highland Grove, Worksop .. .. (1916-17)

SADLER, EDWARD, Newlands, Watlands Avenue, Wolstanton (1917-18)
SAILLY, PAUL, Compagnie Générale d'Electro-Céramique, 64, Rue Franklin, Ivry-Port, Seine, France .. .. (1917-18)
SALT, F., Central School of Science, Stoke-on-Trent .. .. (1922-23)
SANITER, E. H., Phoenix Special Steel Works, The Ickles, Sheffield .. .. (1916-17)
SANKEY, C. H., Wildcroft, Chislehurst, Kent.. .. .. (1916-17)
SATCH, SHINZO, Esq., Tokio Electric Co., Ltd., Kawaski, Kanagawa-Ken, Japan.. .. .. (1920-21)
SAXTON, C., 35, Bedford Street, Strand, London, W.C., 2 .. (1918-19)
SAYER, JAMES, Junr., Hill Crest, James St., Stoke-on-Trent (1912-13)
SCHURECHT. H. G., Ceramic Department, U.S. Bureau of Standards, Washington, D.C., U.S.A. .. .. .. (1922-23)
SCRIVENER, E. D., c/o Messrs. Taylor, Tunnicliff & Co., Eastwood, Hanley .. .. (1908-09)
*SCOTT, A., M.A., D.Sc., Central School of Science and Technology, Stoke-on-Trent .. .. (1917-18)
*SEARLE, A. B., The White Building, Sheffield.. .. .. (1907-08)
*SHAH, C. P., Nadiad, B.B.C.I. Ry., India.. .. .. .. (1913-14)
SHANKS, D., Raisdale, Barrhead, N.B. .. .. .. (1905-06)
SHAW, A. G., Whitebrick Brick Works, Darwen, Lancs. .. (1918-19)
SHAW, RITCHIE, Fylands Fireclay Works, Bishop Auckland, Co. Durham .. .. (1922-23)
SHELLEY & Co., Foley China Works, Fenton, Stoke-on-Trent (1921-22)
SHENTON, E., Wedgwood & Co., Tunstall .. .. .. (1903-04)
SHERLOCK, A., Winterton Pottery, High Street, Longton .. (1916-17)
SHIRLEY, T. H. F., Walton Lodge, Stone, Staffs. .. .. (1921-22)
SIEURIN, E., Höganas, Sweden .. .. (1922-23)
SILLARS, D., Bidston, Britannia Terrace, Saltburn-by-the-Sea (1918-19)
SIMPSON, T. A., Lyndhurst, Wolstanton .. .. .. (1914-15)
SIMPSON, T. G., 34, Elm Street, Cobridge, Stoke-on-Trent.. (1917-18)
SIMPSON, W. A., 27, Kensington Rd, Oakhill, Stoke-on-Trent (1916-17)
SIMPSON, E., 35, Pynest Street, Shelton, Stoke-on-Trent .. (1918-19)
SINGER, Dr., Felix, Charlottenburg 2 Carmerstr. 18 .. (1924-25)
SINGH KRISHEN, Katni Cement Factory P.O. (C.P.) India .. (1921-22)
SMART, H. E., Mountain View, Kidwelly, Carmarthenshire.. (1916-17)
SMITH, H. PROCTER, Hawarden Bridge Steel Works, Shotton, Chester.. .. .. (1916-17)
SMITH, OLIVER, Lilac House, Hunwick, Willington, Co. Durham .. .. (1916-17)
SMITH, F.R., Eastfield, Ironbridge, R.S.O., Salop .. .. (1902-03)
SNEYD COLLIERIES, Ltd., Burslem .. .. (1916-17)
SNOW, WILFRED, R., G.P.O. Box No. 525, Adelaide, South Australia .. .. (1918-19)
SOCIETIE DES PRODUITS CERAMIQUES ET REFRACTARIES, 4, Rue Blanche, Paris .. .. (1918-19)
SOHO POTTERY Ltd., Elder Works, Cobridge, Stoke-on-Trent (1921-22)
SOMERVILLE, W., The Cottage, Hindlow, Buxton
SOSMAN, R. B., 2801, Upton Street, Washington, D.C., U.S.A. .. .. (1918-19)
SOUTH METROPOLITAN GAS Co., 709, Old Kent Road, London, S.E. 15 .. .. (1917-18)
SPEIRS, C. W., The Morgan Crucible Co., Battersea Works, London .. .. (1916-17)

SPROAT, IRA E., c/o R. T. Vanderbilt & Co., 50, East 42nd Street, New York, U.S.A. .. .. (1923-24)
STANLEY BROS., Ltd., Nuneaton .. .. (1922-23)
STANLEY, CYRIL, Stanley Bros. Ltd., Brick Works, Nuneaton (1921-22)
*STANLEY, WALTON, Cotton Bros. Portland Road, Longton (1911-12)
*STANYER, A., 24, Jenkins Street, Burslem .. .. .. (1903-04)
STANWAY, P. W., Clive House, Clive Street, Shelton .. (1921-22)
STATON, A. D., 37, King's Avenue, Wolstanton, Stoke-on-Trent .. .. (1920-21)
STEELE, H. L., Messrs. The Britannia Pottery Co., Ltd., 136, Glebe Street, St. Rolox, Glasgow .. .. (1912-13)
STEIN, JOHN G. & Co., Ltd., Bonnybridge, Scotland .. (1916-17)
STEIN, JOHN G., Millfield, Polmont, Scotland .. .. .. (1923-24)
STEIN, Lt.-Col. ALLAN, Glenbervie, Larbert, Scotland.. .. (1923-24)
STEPHENS, ALFRED, Sir, Broomhill, Kidwelly .. .. (1916-17)
STEVENSON, H. W., Royal Pottery, Burslem .. .. (1913-14)
STEVENSON, SAMUEL, 59, Elm St., Cobridge, Stoke-on-Trent (1921-22)
STOTT, VAUGHAN H., 9, Elmers Drive, Teddington, Middlesex.. .. .. (1920-21)
STOTT, C., Salem Magnesite Works, Suramangaham, Salem District, Southern India .. .. (1923-24)
STOURBRIDGE REFRACTORIES Co., Ltd., Pensnett, nr. Dudley .. .. (1916-17)
STOURBRIDGE FIREBRICK TRADE (Secretary, Mr. Wm. Fullwood), Church Street, Chambers, Stourbridge.. .. (1923-24)
STOVER, E., 474, West State Street, Trenton, U.S.A. .. (1903-04)
STRINGER, G. E., Wynberg, Newcastle Road, Stone, Staffs. (1918-19)
STUBBS, R., 8, The Avenue, Blythe Bridge .. .. .. (1920-21)
SUR, M. M., 65/2, Serpentine Lane, Calcutta .. .. .. (1922-23)
SUTHERLAND, W. FRANK, 79, Normandy Buildings, Toronto, Ont., Canada .. .. (1918-19)
SWIFT & NETHERWOOD, Lepton, Fenay Bridge .. .. (1921-22)
SWINNERTONS, Ltd., Vulcan Pottery, Hanley, Stoke-on-Trent (1918-19)

TAMS, H., Wharf Street, Longton, Stoke-on-Trent .. .. (1913-14)
TARRANT, W. G., Ltd., Byfleet, Surrey .. .. (1921-22)
TAYLOR, F. E., Trentham, Staffs. .. .. (1913-14)
THEOBALD, L. S., The Limes, Hartshill, Stoke-on-Trent .. (1923-24)
THOMAS, C. W., c/o Messrs. E. J. & J. Pearson, Ltd., Brierley Hill, S. Staffs. .. .. (1903-04)
THOMAS, C. A. G., Clifton House, Old Swinford, Stourbridge (1921-22)
*THOMASON, W., Hindleshaw, Nelson Road, New Malden .. (1909-10)
THOMPSON, H. H., 52, Lombard Street, Birmingham.. .. (1921-22)
THOMPSON, J. H., The Vicarage, Leek, Staffs... .. .. (1922-23)
THORLEY, J. P., "Glenelg," Victoria Road, Newcastle.. .. (1923-24)
THRELFALL, C. R. F., c/o Timmis & Co., Stourbridge .. (1920-21)
THURSFIELD, W. T., Hillcrest, Greeenbank Road, Burslem (1921-22)
TIDY, CHARLES J., c/o The Cemaes Brick & Tile Works, Cemaes, Anglesey .. .. (1921-22)
*TIMMIS, G. H., Storrage House, Wribbenhall, Bewdley .. (1916-17)
TOOGOOD, H. J., The Poplars, Elland, Yorkshire .. .. (1918-19)
TOOTH, W. E., Claridge House, Woodville, Burton-on-Trent (1913-14)
*TOWNSEND, H., Mount Avenue, Hartshill, Stoke-on-Trent (1909-10)
TREDDENICK, WM., 3, Primrose Hill, Newfield, Willington, Co. Durham .. .. (1921-22)
TROOP, R. S., The Limes, Hartshill, Stoke-on-Trent .. .. (1923-24)
*TURNER, F., Cranleigh, Brampton, Newcastle .. .. (1900-01)
TURNER, Prof., W. E. S., D.Sc., Department of Glass Technology, The University, Sheffield .. .. (1916-17)
TWYFORDS Ltd., Cliffe Vale Potteries, Hanley, Stoke-on-Trent (1923-24)

UNITED COLLIERIES, Ltd., 109, Hope Street, Glasgow .. (1916-17)
UNIVERSITY OF WASHINGTON LIBRARY, Seattle, Washington .. .. (1920-21)
UNIVERSITY OF CALIFORNIA LIBRARY, Berkley, California, U.S.A. .. .. (1920-21)

VERZOCCHI, P. Corso Italia 1, Milan, Italy .. .. .. (1923-24)
VIGGARS, G. H., The Villas, Silverdale, Staffs... .. .. (1922-23)
VICKERS, A. E. J., 27, Lily Street, Wolstanton, Stoke-on-Trent .. .. (1918-19)

WADE, G., High Street, Burslem .. .. (1914-15)
WAGNER, W. G., c/o George T. Holloway & Co., Ltd., 13, Emmett Street, Limehouse, London, E. 14.. .. .. (1922-23)
WAGNER, B. F., C/o The Coonley Manufacturing Co., Cicero, Ill., U.S.A. .. .. (1923-24)
WAGSTAFF, J. J., 51, Oulton Road, Stone .. .. .. (1921-22)
WALKER, E. E., The Australian Tesselated Tile Co., Ltd., Mitcham, Victoria, Australia .. .. (1916-17)
WALKER, F. W., Art Tile Works, Beaver Falls, Pa, U.S.A. (1906-07)
WALKER, JOHN, The Gate Farm Fireclay & Firebrick Works, Kingswinford, near Dudley .. .. .. (1916-17)
WALTON, C. J., Forsbrook, Stoke-on-Trent .. .. .. (1912-13)
WARBURTON, T. H., The Monk Bridge Iron & Steel Co., Ltd., Leeds .. .. (1916-17)
WARD, T. W., Endcliffe Vale House, Sheffield .. .. (1917-18)
WATERHOUSE, JAMES, Ltd., Soho Works, Wakefield .. (1916-17)
WATTISON, J. T., Rua Candid dos Reis 103, Oporto .. .. (1918-19)
*WATKIN, E., Greyholme, The Greenway, May Bank, Stoke-on-Trent .. .. (1916-17)
WATKIN, T., Harding Terrace, Sheppard St., Stoke-on-Trent (1904-05)
WATTS, A. S., Lord Hall, O.S.U., Columbus, Ohio, U.S.A. .. (1910-11)
WEBSTER, J. C., Bridge Pass, Victoria Road, Tunstall .. (1910-11)
WEBSTER, JAS., Lynve, Victoria Road, Tunstall .. .. (1913-14)
WEDGWOOD, Miss A., The Woodhouse, Cheadle, Staffs. .. (1916-17)
WEDGWOOD, ERNEST, B., The Grove, Wolstanton.. .. (1916-17)
*WEDGWOOD, F. H., c/o Josiah Wedgwood & Sons, Ltd., Etruria, Stoke-on-Trent .. .. (1905-06)
WELLINGTON GAS Co., Courtney Place, Wellington, N.Z.
WELLS, J. H., 10, Glanbrydan Avenue, Uplands, Swansea.. (1916-17)
WENGER, A. H., Trentham Priory, Staffs. .. .. .. (1902-03)
WENGER, F. E., The Hollies, The Brampton, Newcastle Staffs (1905-06)
*WENGER, T. L., Victoria House, London Road, Newcastle .. (1922-23)
WERNER, E. A. R., 174, Corporation Street, Birmingham.. (1920-21)
WERNER, EDWARD, Warsaw al. Ujazdowska 36 .. .. (1924-25)
WEST COAST PORCELAIN MFGS., Millbrae, California, U.S.A. (1923-24)
WESTS GAS IMPROVEMENT Co., Ltd., Albion Iron Works, Miles Platting, Manchester .. .. (1923-24)
WHISTON, H. W., 12, Hollings Street, Fenton, Stoke-on-Trent (1920-21)
WHITELEY, A., 7, Glen Road, Netheredge, Sheffield.. .. (1917-18)
WHITELEY, J. H., 11, Cambridge Street, Saltburn, York. .. (1918-19)
WHITFIELD, T. S., c/o The Cobridge Brick Co., Burslem .. (1905-06)
WIDEMANN, R. V. E., 30, Rue des Dames, Paris (xvii.) .. (1922-23)
WILD, ARTHUR, Hawthorn Dene, Hathersage .. .. (1916-17)
WILKINSON & SON, S., Blackley Fireclay Works, Elland Yorks. .. .. (1916-17)
WILKINSON, A. J., Ltd., Burslem, Stoke-on-Trent .. .. (1922-23)
WILLIAMS, C. P., M.Sc., Flwdwycet, Penrycae, Port Talbot (1916-17)
WILLIAMS, F. R., 1, Beaconfield Villas, Brighton .. .. (1902-03)
*WILSON, S. T., Park Works, Fenton, Staffs. .. .. .. (1904-05)

WILSON, L. M., Whiteley Wood, Sheffield .. .. .. (1923-24)
WILTSHAW & ROBINSON, Carlton Works, Copeland Street, Stoke-on-Trent .. .. (1916-17)
WINKLE, L. H., Colonial Pottery, Stoke-on-Trent .. .. (1908-09)
WINNICOTT, A. B. (Mrs.), 89, Ditton Hill Road, Surbiton, Surrey .. .. (1918-19)
WOOD, A. R., c/o Pilkingtons, Ltd., St. Helens, ... (1920-21)
*WOOD, H. E., Hillside, Hamil Road, Burslem.. .. : (1900-01)
WOOD, H. F., The Uplands, Brampton, Newcastle, Staffs. .. (1911-12)
WOOD, ROBERT, Quarry House, Dudley, Worcestershire .. (1921-22)
*WOOLDRIDGE, F., Taylor, Tunnicliff & Co., Hanley .. (1905-06)
WORKINGTON IRON & STEEL Co., Ltd., Moss Bay, Workington .. .. (1916-17)
*WORTHINGTON, F. S., 2, Grove Place, Shelton, Hanley .. (1907-08)
WRAGG, THOS., & SONS, Storrs' Fireclay Works, Loxley, near Sheffield .. .. (1916-17)
WRAGG, THOS., & SONS, Swadlincote.. .. .. .. (1917-18)
WRIGHT, J. E., 153, Cauldon Road, Hanley .. .. .. (1914-15)
WRIGHT, W. T. & Co., Ltd., Sileby, near Loughboro' .. (1921-22)

The numbers in brackets denote the session of election.

Any change of postal address should be communicated to the Assistant Secretary,

A. RIGBY, Pottery Laboratory, Stoke-on-Trent.

Student Members.

ASH, S., 7, Albut Street, Goldenhill, Stoke-on-Trent .. (1922-23)

CHAMBER, A., "Littlewood" Worsley, Manchester .. .. (1924-25)

GREEN, R. A., 3, Brocksford Street, Fenton .. .. .. (1924-25)

HANCOCK, N., 138, Dimsdale Parade, Wolstanton .. .. (1924-25)
HEAP, J. W., 9, Morley Street, Tunstall.. .. .. .. (1920-21)

JONES, A. G., 14, Boulton Street, Birches Head, Hanley .. (1923-24)

MANSHARAMANI, G. T., 254, Princes Road, Penkhull .. (1924-25)

PADDOCK, G. J., "Coatbridge" Basford .. .. .. (1924-25)

STEVENSON, J. H., 125, Dimsdale Parade, Wolstanton .. (1923-24)
SHAW, W.F., 48, Albert Street, Sandford Hill, Longton .. (1924-25)

Proceedings—Session 1923-24.

The first meeting of the session was held on Monday, 12th November, 1923, in the Central School of Science, Stoke-on-Trent. Mr. H. E. Wood presided. About 60 members were present, also members of the National Council of the Pottery Industry by invitation. Apologies for absence were received from Mr. F. Hand and Mr. A. B. Jones, Jnr. Nominations for membership were received on behalf of the following : Ordinary memberships : Mr. A. Harrington and Mr. W. H. Bossons ; Student memberships : Messrs. H. A. Price, A. W. Dawrant, A. J. Lewis, A. J. Reid, J. H. Stevenson, J. Hargreaves, A. G. Jones, W. S. Adams, P. A. Ryles, R. S. Smith, R. S. Morris, L. Bullin, J. Bentley, Jnr., D. S. Pillay. Reference was made to the death of Mr. Henry Watkin (Past President) and Dr. J. E. Stead (Vice-President). A vote of sympathy with the relatives was passed. Mr. A. E. Harris read a paper entitled "Collecting Flint Dust." The meeting passed a vote of thanks to Mr. Harris who replied to questions raised by Mr. Werner and Mr. Fielding.

General Meeting held in the Central Science School, Stoke-on-Trent, on Monday, 10th December, 1923. Mr. H. E. Wood presided over an attendance of about 48 members. Apologies for absence were received from : Dr. A. Scott, Mr. B. J. Moore and Mr. W. Emery. Proposals for membership were accepted for Messrs. T. Arrowsmith & Sons, Ltd. (Collective) ; Mr. Wm. Hugill and Mr. H. C. Johnson (Individual). Dr. G. Martin gave a paper : "Researches on Fine Grinding." Mr. C. E. Ramsden resigned from the position of Hon. Auditor and Mr. G. Campbell was elected to the vacancy.

General Meeting held in the Central Science School, Stoke-on-Trent, on Monday, 14th January, 1924. Chairman—Mr. B. J. Moore ; Attendance, 44. Apologies for absence were announced on behalf of Messrs. H. E. Wood, T. A. Simpson and W. Emery. The following were proposed as new members : Ordinary memberships : Masanobu Nakatsuji, Heinrich Koppers, Ira E. Sproat ; Student memberships: R. Hull, Jnr. Mr. J. Ludlow gave a paper entitled "National Ventilation" and Mr. B. J. Moore, Mr. Werner and Mr. Newman took part in the discussion which followed.

General Meeting held in the Central Science School, Stoke-on-Trent, on Monday, 11th February, 1924. Mr. H. E. Wood presided over an attendance of 48. The following were nominated for membership : Ordinary : Messrs. F. W. Davies, B. J. Wagner, F. Heath, W. A. MacLeod, West Coast Porcelain Manufacturers ; Student : Mr. W. Foskett. A paper entitled "Methods of Pottery Manufacture—30 years ago and to-day" was read by Mr. John

Miles. A discussion followed in which Messrs. H. E. Wood, C. D. Grimwade, W. Emery and T. A. Simpson joined.

An open Meeting held on Monday, 10th March, 1924, in the Central School of Science, Stoke-on-Trent. About 120 members were present and Mr. H. E. Wood presided. Mr. A. Hollins gave a paper entitled: "Improperly pugged clay and its effect on:—(1) The wage-earning capacity of the operative; (2) The loss by defective ware to the employer." A discussion followed in which Messrs. H. E. Wood, H. Plant, F. Turner, F. Lane, B. J. Moore, W. Shaw, D. F. W. Bishop and F. Wooldridge took part.

General Meeting held in the Central School of Science, Stoke-on-Trent, on Monday, 7th April, 1924, Mr. H. E. Wood presiding over an attendance of 45. Mr. C. H. Yeaman sent an apology for absence. Proposals for membership were received on behalf of the following:—Ordinary: Mr. H. Halliday, Wm. Hitchen, C. P. Wood, R. Ferguson. Mr. F. S. Worthington communicated a note on "Variation in the size of jugs cast with slips of different weights per pint" and the following discussed same: Messrs. H. E. Wood, A. Leese and C. D. Grimwade. Mr. A. Watkin gave a paper entitled: "Electrical Porcelain: the effect of varying the composition on some of its properties." Mr. J. F. Langton, M.Sc., contributed to the discussion on this paper and the following spoke on the same subject: Messrs. H. E. Wood, C. D. Grimwade and Dr. A. W. Ashton.

Annual Meeting held in the Central School of Science, on Monday, 28th April, 1924. Mr. J. A. Audley presided over an attendance of 35. Mr. F. S. Worthington had sent an apology for absence. The Council's Annual Report was read and adopted. Officers for the Session 1924-25 were elected. Dr. J. W. Mellor read three short papers: (1) "Terra-Sigillata, not Samian Ware"; (2) "The Discovery of China Clay in Europe"; (3) "Use of Fluorspar in Leadless glazes." Mr. B. Olsen gave a paper on "The use of Wood-wool for Packing Purposes." There was a short discussion on the note read by Mr. Worthington at the previous meeting.

Proceedings of the Refractory Materials Section of The Ceramic Society.

General Meeting held on Thursday, 4th October, 1924, in the Grosvenor Museum, Chester. Mr. T. Arthur Acton opened the meeting with a "General Sketch of the Geology of the Chester District," after which the following papers were read: "Improvements in Drying Refractories or other Goods," by Mr. J. Holland and Mr. W. J. Gardner; "The Zenith Temperature," by Dr. J. W. Mellor; "Glass House Pots," by Mr. W. J. Rees, B.Sc. During the afternoon the members visited the works of the Bwlchgwyn Silica Company Ltd., at Bwlchgwyn, calling at their clay pit en route. At night the members and friends dined at the Queen Hotel, Chester. The President—J. Holland, Esq., presided.

On Friday, 5th October, 1924, a business meeting of the section was held. Apologies for absence were received from: Messrs. W. Hassall, G. R. L. Chance, A. S. W. Odelberg, J. Dunnachie, J. P. Leather, H. E. Mason and Dr. H. G. Colman. Nominations for membership were received on behalf of the following: Collective: Wests Gas Improvement Co., Ltd., B. R. Rowland & Co.: Individual: Messrs. J. Mear, L. Holdcroft, W. McGavin, H. A. Morfey, J. A. Mobberley, C. Stott, C. E. Bales, P. H. Tunnicliffe, A. Amand, W. T. Coe, L. M. Wilson, N. P. Holdcroft, L. S. Theobald, Dr. F. Kanhäuser. Officers for the next session were elected. The President gave notice to create a new district—North of England—for representation on the Council. A vote of thanks was passed to the Local Secretaries—Mr. T. Arthur Acton and Mr. C. Jones—for the excellent work they had done in arranging the Chester Meeting, also for the kindness of their firm who permitted the members to visit their works and provided conveyances for the party from Chester to Bwlchgwyn and Tea at Bwlchgwyn; also to the Mayor and Corporation of the City of Chester for providing accommodation for the meetings. Following the business meeting, papers were read as follows:—"Notes on the Proctor Dryer," by Mr. C. H. Middleton; "New Methods of Producing Gas for Industrial Purposes" by Mr. R. Maclaurin; "The Effect of Salty Coal upon Refractory Materials" by Mr. L. M. Wilson, M.Sc. During the afternoon a small party of members visited the works of Messrs. Lever Bros., Ltd., Port Sunlight. The following paper: "Carbonisation of Clays" by Mr. W. Smith brought the meeting to a close:—

Carbonisation of Clays.

THE principle underlying the clay carbonisation process may be defined as a utilisation of molecular contractive force; in effect, the utilisation of the contractive force which operates in final stages of the initial burning of clays, known in-

dustrially as a "closing" of the material. If a relatively coarse substance be employed to resist this contraction, the clay body itself will crack, thus defeating in some measure the object in view, while if a material be introduced into the clay susceptible of chemical combination under heat, there will be a tendency towards fusion. Thirdly, if a substance be used, compressible in itself, the contractive force operating in the clay will practically be unimpeded, and no subsequent physical change in the structure of the material may be evident.

A suitable element, embodying the necessary qualities, has been found in atomic carbon, intensively diffused throughout the clay substance, as nearly as possible to be figuratively thought of as ether appears to permeate matter. This condition can be brought about by saturating clay at a certain stage of heating with hydrocarbon gases or volatile hydrocarbons under pressure. These gases absolutely permeate the clay substance, conveying carbon to the minutest particles, wherein the element is deposited in atomic form, owing to dissociation of the gases in contact with the clay. While the contractive force of the clay is not utilised until the final stages of firing, the carbon charge is given in the earlier period known as "biscuit." The material is then in a state of maximum porosity, and embodies extremely high absorbent qualities. After receiving the carbon charge, the biscuit clay is black, and will remain so after pulverisation to particles scarcely visible under a powerful microscope; thus proving that the substance is saturated to the highest degree. No form of mechanical mixing brings about an identical composition, since the atoms of carbon and molecules of clay appear to be so intimately associated, that closer union would only be possible by chemical combination. In this substance, the contractive force of the clay is expended during subsequent heating, enclosing the particles of carbon with great pressure, and forming a composite body approximating in hardness to agate. Though dense to this exceptional degree, the product is susceptible of conversion into a microscopically porous structure by firing in a strongly oxidising flame, and in that condition the heat-resisting and refractory properties are highly increased. There are many phenomena arising out of carbonisation, but for the purposes of this paper we shall confine ourselves to the heat-resisting properties, and incidentally, to the abrasive qualities of the material.

No chemical change has, so far, been determined in the fundamental constituents of an average clay after the material has been subjected to the process. That is to say, if the clay employed be Al_2O_3-$2SiO_2$ before carbonisation, it will represent the same formula by analysis after application of the treatment. A considerable alteration, however, in the physical condition should occur in the relative proportions of the impurities. If the clay be properly

carbonised, these impurities will be considerably reduced. Carbonisation therefore brings about a purification of the clay; but an explanation is required as to what occurs in addition to purification. The clay contraction, while not necessarily great in volume, is exceedingly powerful. The infinitely minute particles of carbon offering resistance are subjected to pressure from all directions, enclosing them in a kind of universal vice. The particles exist in countless numbers, since they are deposited there by gases containing carbon in chemical combination. For anything we know, an efficiently carbonised grain of ball clay, two or three millimetres in diameter, may contain a million of these particles. The black body so produced, resembles what the body of an ordinary plumbago crucible might exhibit, if made under the highest possible mechanical pressure. But the carbonised material presents more than this, because the plumbago crucible would still contain a large proportion of clay particles into which the mechanically mixed carbon had not been forced, while the carbonised clay is permeated completely throughout with an atomic and evenly distributed charge of the element. The product in this state is known as black carbonised clay; a more desirable term for industrial purposes might be "carbonite." Owing to its hardness, and an amorphous structure which gives toughness, this product is best adapted for abrasives, for mixing with cement, for road-making or other wear and tear purposes. It is also very refractory to heat when conditions are such that air is excluded during work, and its resistance to acids under all conditions is perhaps unsurpassed by any other silicious or aluminous material. It should also be noted that clay carbonised in the black state is impervious to weather or atmospheric action. Under these influences the carbon, once enclosed, will remain in the material indefinitely.

We now approach the form presented as white carbonised clay, a more exact term for which might be "carbo-calcined clay." This is the material after the carbon has been burnt out in a high temperature oxidising flame. Contraction occurred while the product was undergoing manufacture in the carbonising gases. It then enclosed the atomic carbon. On burning out the carbon, an identical number of infinitely minute pores remain in the material, where originally the carbon particles were lodged. This artificially produced porosity gives the carbonised, or more correctly the "carbo-calcined clay," its properties for general heat-resisting and refractory purposes. While no perceptible changes have occurred in the relative proportions of silica and alumina, the mechanical structure of the body is considerably transformed. The destruction of most heat-resisting materials is brought about by fusion, or reduction of the original individual constituents from solid to a semi-liquid condition. But the carbo-calcined clay reached the critical contraction limit in the presence of atomic carbon, and since the carbon has been burnt out, the tendency

towards fusion has been checked and transferred to a higher degree in the thermo-chemical scale. In practice, when again subjected to heat, the flame passes through the minutely porous material similarly to the manner in which it would play through asbestos or alumina. Destruction will, of course, come if the heat is sufficiently intense, but carbo-calcined clay in general, refuses to melt at anything near the same temperature as that of the original material. By carbonisation we have, therefore, a clay not only partially freed from impurities, but so altered in the physical state that it is vastly more durable as a heat resisting agent than the same substance untreated.

It does not always follow that a laboratory temperature test is a criterion of the prolonged heat-resisting qualities of a carbo-calcined brick. Clays vary in effects manifested by carbonisation. In some cases, it may be that the melting point of a treated fragment fired in the laboratory may not be very considerably higher than that of the untreated material, but when made up into bricks or other articles, the durability of the carbonised product in the industrial furnace will possibly be many times greater than that of articles produced from the natural clay. This has been confirmed in practice many times, and arises from the fact that the carbo-calcined brick is not only immune to the weakening effects of continued heatings, but the action of destructive vapours, corrosive slags and erosive metals, is modified or neutralised by the peculiar physical condition of the minutely porous product. These heat tests apply only to certain clays; in others, the actual melting point is highly increased both by carbonisation and by the subsequent carbo-calcining treatment.

It is now necessary to examine more closely the conditions which bring about the physical changes referred to. In working the process, purification is effected by means of volatilisation and mechanical discharge of gases, and by forces expended generally during decomposition of the volatiles temporarily confined in the heated granular clay through which the gases are caused to pass. Iron pyrites and ferric oxide are reduced to metallic iron, which at high temperatures is volatilised and carried up towards the surface of the mass. The alkalis, lime, and titanic oxide are also reduced and volatilised owing to the highly reducing conditions and intense heat. These facts are apparent by the accumulation of considerable quantities of burnt iron, ferro-silicates, and other combinations at the surface of the material found on cooling down. Sulphur is volatilised at comparatively low temperatures. While the impurities are being expelled, the clay itself is receiving and retaining the charge of carbon as already described. In the case of siliceous clays, or ganister, the intense molecular vibration of the highly heated substance produces microscopic expansion of each crystalline particle, which appears to permit absorption of the

gases during the continuous heating. As an example, this phenomenon may be demonstrated visually as follows.

If grains of transparent quartz, such as rock crystal, are employed, the material after treatment will be found to have lost transparency, and to have become opaque or milky white, resembling particles of marble. Thus the gases in transit have essentially affected the transparent silica, transforming both exteriorly and interiorly the molecular structure. Sand, ganister and siliceous stone, are acted upon similarly to quartz, in each instance the dominating colour of the grains being opaque or milky white after treatment by the hydrocarbon gases, as against transparent, or semi-transparent after firing in an open flame. A further effect of the action on ganister, siliceous clays or silica, is perceptible by increased angularity and sharpness of the particles constituting the charge. This is accounted for mainly by a shattering of the particles, owing to heat and dynamic energy of the compressed gases in transit. In the case of silica and other crystalline bodies, the particles undergo extensive surface fracture, and frequently complete cleavage of each particle. It is well known that a good ganister should be composed of grains having sharp irregular outline and angularity of form, in preference to smooth globular formation of the particles. This latter composition constitutes, in fact, a defect; but when such ganisters or sand-stones are subjected to the action of volatilised hydrocarbons according to the process, the product will be found to consist of irregular-shaped grains, each with an abundance of facets and sharp edges, thus bringing up the composition of such materials to the highest grade ganisters physically, together with the improvement and enhanced qualities of each individual particle, brought about by the carbonising treatment. The binding of carbonised clay is accomplished by pressure, just as with magnesite. Artificial binders should be used sparingly, and in the case of carbo-calcined materials, the binder should preferably be of the same composition as the original clay. The general reactions of a carbonised silica brick may be regarded as acid, those of a first-grade fireclay, neutral, while those of a highly aluminous clay, such as bauxite, tend towards basic. A proposition relating to the physical changes occurring under the process may be advanced as follows.

It is now known that the molecules constituting certain materials have the property of being able to arrange and re-arrange themselves under the effect of heat, so as most effectually to resist the exigencies as they arise at increasing temperatures. For example, the molecules of a clay at mean atmospheric temperature might, for the purposes of illustration, be imagined as infinitely minute oblong blocks, cohering without order or form. At 250°C. we will assume that these blocks break up into equal sided squares or cubes, still in disorder, having the appearance of dice shaken up in a vessel. At a higher temperature, say 500°C., the atoms of each

molecule adapt themselves so as to form globular or spherical bodies, all with their surfaces in contact. At still higher temperatures, the spheres close up and compress each other, until, if a section of the mass could be seen, it would present the appearance of a honeycomb, or hexagonal formations, permitting no spaces or interstices whatever to exist in the mass. In this state, the heat finds no path except through the dense aggregation of compressed molecules. The last stand is, therefore, made before the change from solid to liquid, or from rigidity to mobility, is reached. This crude illustration is merely suggested as an aid to realising figuratively how the molecules adapt themselves to the most advantageous forms and positions for resisting the stages of increasing heat, until the material reaches a fusion point. Is it possible, therefore, that changes somewhat resembling those suggested, can more effectually be performed in the porous structure of carbo-calcined clay, than in the dense natural material with its lower fusion point? At any rate, the powers of resistance to heat, latent in carbonised clay, appear to be due to physical conditions rather than to any possible chemical changes as between clay and carbon, apparent in the treatment.

Having given an outline of the process, and a brief theoretical explanation of some causes which appear to effect the changes described, we will deal with certain results obtained in recent work. An important conclusion reached is embodied in the statement that carbonisation increases the normal formation of sillimanite in aluminium-silicates. This fact can best be demonstrated by micro-photographs.*

In a sample of Ayrshire bauxite in the raw state, a highly magnified layer consisting only of grains similar to fine sand, is observed. Particles of the same clay after firing to about 1,450°C., exhibit sillimanite needles only very occasionally, and may be taken as representative of the normal part formation which occurs under ordinary heating processes. The carbonising process has the effect of increasing enormously the sillimanite in these samples.

The materials composing these slides were checked, and counter-checked until there was no doubt as to the certainty of the results obtained. It is possible to convert a very large proportion of a high-grade clay into sillimanite. If a clay is carbonised, and fired to about 1,700°C, it will exhibit a structure consisting essentially of pure sillimanite, the whole mass of clay showing an abundance of the characteristic crystalline needles.

It is unnecessary to emphasise the significance of these results, since they prove not only one of the effects of properly conducted carbonisation, but the possibillty of converting clay into sillimanite, the purity and durability of which are known. The extent to which sillimanite formation may be carried is governed

*Unfortunately, the photographs referred to are not suitable for reproduction here.

largely by the nature of clay used, but it may be stated that, by special treatment of certain clays, the production of a brick, retort, and crucible consisting mostly of sillimanite is not only in view, but on a small scale has been accomplished. Bricks made from carbonised clay may broadly be defined as possessing the following qualities: refractoriness; hardness; non-contractile and non-expansible properties. These latter are not absolute, but very greatly reduced and almost negligible; certainly if finally burnt beyond the temperature at which the bricks are to be exposed in work.

The Ceramic Society.

COUNCIL'S ANNUAL REPORT.

In presenting our Report for the end of the 23rd Session, we have to state that the membership of the Society is somewhat lower than last year, the names of a number of members, whose subscriptions had lapsed, having been removed from the list. At present, the membership stands as follows:—

Honorary	6
Collective	98
Individual	557
Student	15
Total ..	676

We have lost by death a very old member of the Society—Mr. H. Watkin—also Dr. J. E. Stead, F.R.S., a Vice-President of the Refractory Materials Section, Mr. A. F. Wenger, and Mr. W. Sherlock.

The activities of the parent section have been confined to the monthly meetings at Stoke-on-Trent. An interesting feature of the Session was a paper, read by the Secretary of the Pottery Workers' Society, several members of which joined in the discussion.

The Refractory Materials Section held their Autumn Meeting at Chester, and we wish to record our thanks to the Mayor and Corporation of Chester for their kindness in placing rooms at our disposal, also to Mr. T. Arthur Acton and Mr. C. Jones who acted as Local Secretaries.

The Society is now on the eve of a visit to Italy, the party numbering 54.

Several papers will be read at a joint Meeting with the Italian Chemical Society in Rome.

Our grateful thanks are due to the Governors of the Central School of Science and Technology for the use of rooms for our Meetings.

Stoke-on-Trent,
28th April, 1924.

Visit to Italy.

THE party which visited Italy in May, 1924, numbered fifty-four and included members of both the Pottery and Refractory Materials Sections of the Society. Among those present were Mr. J. Holland (Sheffield), president; Dr. J. W. Mellor, hon. secretary; Mrs. Mellor, Sir W. J. and Lady Jones, Miss E. Jones, Mr. and Mrs. J. Burton, Dr. A. Scott, Mr. A. S. W. Odelberg, Mr. and Mrs. E. Sieurin (Sweden), Dr. H. G. Colman (London), Dr. W. L. Freeman (Bristol), Mrs. C. D. Grimwade, Mrs. H. Wood, Messrs. H. T. Arrowsmith, J. Steventon, W. F. Kent, E. J. Ridgway, S. Hawthorne, J. E. Harris, W. Hitchen, D. S. Pillai, D. D. Green, A. Hewitt, W. Lindley, W. S. Lindley, and V. G. H. Alcock (Stoke-on-Trent), Mr. and Mrs. A. Lomas, Miss Lomas, Mr. W. J. Gardner, and Mr. F. Russell (Sheffield), Mr. R. Pickford (Darlington), Messrs. A. H. Carder, C. Carder, and W. H. Price (Stourbridge), Mr. and Mrs. P. Hammond (Macclesfield), Mr. and Mrs. J. W. Fagan (Buxton), Mr. R. S. Wragg (Swadlincote), Mr. F. V. Crawshaw (Parkstone), Mr. A. H. Middleton (Consett), Messrs. G. Renwick and J. A. Gibson (Newcastle-on-Tyne), Mr. and Mrs. F. W. Higgins, Mr. and Mrs. Harvey (Manchester), Messrs. W. Wight, F, Wight and W. Hamilton (Glasgow).

The members of the party assembled in London and left Victoria Station by the 9.15 a.m. train. Although the crossing from Folkestone to Boulogne could not be described as very rough, there was yet sufficient swell to make several members glad that the sea journey was not several hours longer. The four hours available at Paris were spent according to the varied tastes of the individual, but all reassembled at the Gare du Lyon in time for dinner before catching the 9.0 train for Lausanne. Unfortunately, the number of sleeping berths was limited, so that several persons passed the night in the ordinary carriages in a vain endeavour to snatch a few hours' sleep. From Lausanne onwards the journey was continued under ideal conditions so far as weather was concernzd, and magnificent views of the Lake of Geneva and the surrounding mountains were obtained.

Pallanza Fonde Toce was reached about 10 p.m., and the party then drove along the charming but appallingly dusty shore of Lake Maggiore to Pallanza, where the night was spent. It may be remarked that the party made here its acquaintance with the traditionally cloudless skies of Italy, which acquaintanceship remained practically unbroken for the remainder of the trip.

On the Monday the members proceeded by boat across Lake Maggiore to Laveno in order to visit the works of the Societá Ceramica Italiana. There they were met by Mr. Scotti, the managing director, who, after welcoming them to Italy, conducted them

over the works. The latter, which are most pleasantly situated on the steep hillside which faces the lake, are of considerable extent, the number of employees approaching three thousand. The products manufactured include porcelain, earthenware, electrical fittings, and refractory goods. The first part of the works to be visited were the stores for the raw materials. These which were comparatively new, were substantially built and planned on a very generous scale, being capable of housing at least six months' supply of clay, quartz, and so forth. The mode of transport thence to the mill, by waggons drawn by horse or bullock, is shortly to be substituted by a more expeditious method. In the mill much of the grinding was done by means of cylinders, the quartz being first calcined in a vertical kiln. The mill house was likewise large, as not only were several types of "clay" prepared, but also dust for tiles, and casting slip, as well as the colours both enamel and underglaze. The plant in the mill and slip house generally was of the usual type, but is was interesting to note that most of the machinery was made on the works, there being a large machine-shop which was afterwards visited by the party. From the slip house the members proceeded to the mould-making department, and then to the making shops, where, although most of the oreinary processes were seen in operation, jolleying was the method which was chiefly used. The biscuit ovens were all of the down-draught type. In the dipping house an interesting feature was the use of an aerograph dipping machine for tiles. The intermittent glost ovens were also down draught, but much of the glost ware was fired in a Dressler tunnel oven which was installed in July, 1922, and which was said to be working successfully for the firing of general ware. The substructure of the trucks was hollow and was being utilised partly for the hardening on of underglaze colours and partly for the firing of enamel colours. In the decorating shops, hand decorating, stencilling, printing, and aerographing were all being used, and a great variety of decorated ware was being produced.

At the lunch, to which the party were subsequently entertained by Societá Ceramica Italiana, a welcome to Italy was given the members by Mr. Scotti, who expressed his appreciation of their visit to the factory at Laveno, and hoped that such visits might be repeated at future dates. On behalf of the Ceramic Society, Mr. J. Holland, the president, responded and thanked the "Societá" and Mr. Scotti for the kindness in showing the party the works, and also for their great hospitality. In the afternoon the members explored the beauties of Lake Maggiore, Mr. Scotti conducting them in a boat to such renowned places as the Borromean Islands. Laveno was again reached early in the evening, and the journey to Milan made by train.

The following day the party drove to the works of the Societá Italiana Ernesto Breda at Sesto San Giovanni, where an inspection was made of the engineering shops and the steelworks. The latter

was interesting on account of the use of electric furnaces for the production of steel, six furnaces of the Herault pattern, having each a capacity of fifteen tons, being in operation. The power to operate these furnaces is obtained from hydroelectric plants belonging to a subsidiary company and situated in the foothills of the Alps. In the afternoon the members inspected the works of the Societá Anonima Materiale Refrattario at Corsico, on the invitation of the Managing Director, Engineer Marchello, who conducted the party over the works. The variety of refractory materials made by this firm includes both silica and fireclay refractories, the latter comprising such products as blast furnace blocks, nozzles, and so forth. Some of the raw materials utilized are native, being obtained from the Simplon region and elsewhere, but clay is also imported from abroad. In the preparation of the raw materials, dry grinding is used to a large extent, with the result that the dust in the mill is rather appalling. Several members of the party wondered what would have happened had silicosis regulations been in operation. The solid products are expressed from a vertical pug and then repressed by hand, while hollow goods are made by expression and fettled. Most of the firing is carried out in rectangular down-draft ovens, but a gas-fired chamber oven allied to the Mendheim type is also in operation. The making shops were large and well arranged, being situated in a modern concrete building with the ovens on the bottom, the waste gases from the latter being utilised for drying. After the works inspection the members were entertained to tea by the company.

On the Wednesday the party drove to Bergamo, some thirty-five miles from Milan. Unfortunately, the day was misty, and the long drive through the rice-fields of the plain was not relieved by any views of the Bergamasque Alps until the town was reached. Immediately on arrival the works of the Societá Gres Ing. Sala & Ci. at Colognola were visited. These works are like those of Corsico, the making shops being over the ovens and the whole place being modern. The production consists chiefly in acid-proof ware of many kinds, and the members of the party were much impressed by the craftsmanship of the workmen engaged in making such complicated articles as aspirators, pumps, and so forth, in a stoneware body. The party were afterwards entertained to lunch by Ing. Sala, the managing director, who, in a short speech, extended a warm welcome to the members. Mr. Holland, in his reply, referred to the ancient traditions of Bergamo, a town of probably Umbrian origin, and stated that the pride of the local people, so far as their town was concerned, was thoroughly justified by the craftsmanship which they had had the pleasure of inspecting that morning in the factory. A factory which could produce such ware was certainly maintaining the traditions of the district. This visit had certainly emphasised the fact that the Ceramic Society had come to Italy to learn, not to teach, and there was no doubt

that what had been seen that day had been eminently instructive. The President concluded by hoping that at a future day the Italian manufacturers might visit England, so that the Ceramic Society could have an oppurtunity of reciprocating the hospitality which it had received in Italy. In the afternoon the "Citta Alta," or Upper Town, was visited, the return journey to Milan being made in the evening.

The following day was occupied by the journey from Milan to Florence and by sightseeing in the latter town. Most of the party left Florence at an early hour on Friday, and proceeded by road to Larderello, where they had been invited by Prince Ginori Conti to visit the fumeroles and boric acid works. On the way a short visit was paid to the historically interesting town of San Cimignano. At Larderello the party were received by Prince Ginori Conti.

The boric acid, together with carbonic acid, sulphuretted hydrogen, and other gases, is contained in the enormous volumes of steam of volcanic origin, which underlies this part of Tuscany. This steam finds its way to the earth's surface and there escapes through the "soffioni" or steam vents. The pressure of steam is very considerable, and may attain as much as fourteen atmospheres. An interesting industrial development is the utilisation of this steam for the generation of electrical power, which is supplied, by high tension transmission, to the neighbouring towns at a price even lower than that of hydroelectric power. The boric acid and so forth are recovered, at Larderello, from the soffioni by condensation processes and then purified by recrystallisation. Amongst the compounds recovered or prepared by the Societá Boracifera di Larderello may be mentioned, in addition to boric acid, borax, perborate of sodium, and ammonium carbonate. Much of the boric acid so produced is utilised in England and elsewhere as a constituent of pottery glazes.

After the examination of the "soffioni" and the works, the members were entertained to lunch by Prince Ginori Conti, who, in the course of a short speech of welcome, mentioned the part played by Englishmen, especially Mr. Edward Wood, in the development of boric acid glazes. Mr. Wood visited Larderello in 1848, and his visit is recorded by the presence of a marble tablet at Larderello. Prince Conti expressed his gratification at the visit of the Ceramic Society, and also at the interest displayed in the production of a humble ingredient of pottery ware. After the President had apolgised for being unable to respond on account of voice trouble, Sir W. J. Jones, on behalf of the Society, thanked Prince Conti for his hospitality, and for the opportunity afforded the members of the party to inspect the mode of production of a raw material so essential in our industry. The return journey to Florence was made by way of Volterra, where a short opportunity of seeing some part of this venerable town was fully exploited by the party.

On Saturday, May 10th, the works of the Societá Ceramica Richard Ginori were visited, where the members were received by Commendatore A. Richard. This factory has been established for almost two centuries and is situated near the village of Sesto Feirentino. A great variety of ware is made, especially porcelain and majolica. The members of the party were first conducted through the museum where there was displayed a wonderful collection illustrating the development of Italian hard porcelain, while in other galleries were to be seen numerous examples of the porcelain of almost every country in Europe. After visiting the museum the party was divided up into several sections and each section was taken through the works where the various processes employed for the manufacture of porcelain were examined.

The stores for the raw materials, the mill, and the slip house were for the usual type. Most of the grinding, apparently, was carried out in cylinders. Different methods of making were in operation, but as is common in Italy, a large amount of material was being jollied. The ovens were mainly of the two-decker type, the easy biscuit fire being carried out in the upper portion of the ovens which was of the up-draught type, while the hard glost fire which is used for hard porcelain was obtained in the bottom portion of the oven where the arrangements were of the down-draught type. The decoration of ware was likewise varied, and comprised of various methods already mentioned in connection with the works at Laveno. For firing the ware with enamelled decoration a continuous circular kiln of a nature similar to the Climax kiln was in use. The manufacture of insulating materials was also shown to the visitors, while the visit concluded in a demonstration of the methods of testing both high and low tension insulators.

The Company entertained the visitors to lunch, when Commendatore Richard spoke in English. He regretted that his knowledge of English prevented him from dwelling as long as he would like to have done on the production of the English potters, but he wished to express his appreciation both of England and of the products made therein which he had had the opportunity of examining during a prolonged stay many years ago. He could never forget the welcome which he received during his visit to England, both by the larger manufacturers and the smaller. He also stated what a great pleasure it was to him to be able to reciprocate the kindness which he had received during his visit to England. He thanked the members of the Ceramic Society for the honour they had done him in visiting his works.

The President of the Ceramic Society, Mr. J. Holland, conveyed the thanks of the Society for the hospitality and kindness which they had received at the hands of so famous a firm as the Societá Ceramica Richard Ginori.

On Sunday the members travelled to Rome where the headquarters of the Society were the Hotel Regina Carlton, and the

Royal Hotel. On the evening of Monday, May 12th, a reception by the Associazione Italiana di Chimica was given, where the members were received by Prof. Nasini, President of the Associazione. After the reception, the members were entertained to tea by the Associazione and a small exhibition of Ceramic ware was examined.

On the following afternoon the members were conducted by Signor Piermattei to the Villa Giulio where a very interesting collection of Etruscan ware was on view; proceeding from there to Maestro Randone's Ceramic School which is situated on the ancient Belisarian walls. Here the present day production of the ancient black and coloured Etruscan ware, known as buccheri, is carried out by Maestro Randone and his pupils.

In the evening the Ceramic Society Dinner was held at the Hotel Regina Carlton. In proposing the toast of the Associazione Italiana di Chimica and Kindred Societies, Dr. Mellor said: "It is the highest honour you could have conferred upon me in asking me to propose the toast of the Italian Chemical Society, and of the Italian Scientific Societies, coupled with the name of Prof. Raffaello Nasino.

A good many years ago I knew more about Rome than I did about the country in which I lived. I should not be speaking the truth if I said they were all pleasant recollections. Our Latin master in those days had a very objectionable practice after each lesson of dusting my clothes *in situ*. Among the few things he was able to beat into me in that manner, was the impression that the civilisation of Britian was related to that of Rome much as that of Zululand is now related to that of Great Britain. To-day, in these very streets I seemed to see the shadows of the old British Generals being dragged in triumph through your streets, but to-day we do not treat our defeated foes in that exciting way: we invent a League of Nations as meek apology for being victorious.

The chastening you gave us in those days did us a world of good; and you have provided abundant occupations for those with an archæological turn in the remains of the Roman occupation of Britain, usually left in the form of Ceramic wares. Although our Ceramic Society does not specialize in archæology, yet, the Samian ware, which your countrymen left behind, has made us do some guessing as to how it was made. No one has yet come up to that standard of glaze.

Our Ceramic Society is a kind of linkage or bond between industrial practice, and pure science. You will no doubt, see to-morrow how very patiently the manufacturer bears up while the purely chemical questions are being disputed—no, discussed. Although these papers are not typical of those presented at our regular meetings, they show, I think, how closely we are bound to your Chemical and other Societies. The bond is even closer than a community of interests, our Society is but one of the numerous offsprings of an early Scientific Society founded in Italy in the 16th Century.

Four hundred years ago, progress in science was impossible, because the thinking world was dominated by theories woven with gossamer threads of so fine a texture that they would not bear contact with gross material facts. So much the worse for the facts ; —for the facts were denied. Fortunately, a small band of workers in Italy clearly recognised the futility of attempting to discover Nature's secrets in such an atmosphere, and they accordingly founded a Society with the object of investigating nature by the pure light of experiment and observation, unclouded by opinions and beliefs founded solely upon authority and common-sense. By discounting authority and common-sense, Italy inaugurated a veritable renaissance in Science ; Italy's example was followed in England by the founding of the Royal Society, in France by the Academie des Sciences, and in Germany by the Berlin Academy. It would be difficult to overestimate the debt which the scientific world in particular, and the whole civilized world in general, owes to the influence of the Scientific Societies first founded in this very country. Unfortunately, Italy was soon sorely oppressed by internal and external enemies ; and those turbulent times were very unfavourable for the growth of Science ; as a result, the Scientific Societies in other countries soon out-stripped those in Italy in volume or quantity of work ; but Italy has never been out-stripped in the quality of her work.

Every school boy in England hears about Galilei, or, as we more familiarly call him, Galileo, although I am sorry to say that their version of the tribulations of Galilei are in the main inaccurate. The names of your Galvini and Volta have been incorporated in our language. Need I mention the galvanic current, and the voltage of that current ? I wonder what chemistry would have been without Avogadro. Manchester is very proud of its Dalton. We are often told that chemistry is founded on Dalton's atomic theory, but it would be more correct to say that Chemistry is founded on Avogadro's theory than on that of Dalton. When I hear this reversed, I am reminded of the dog's tail which thought it wagged the dog. I could go on enumerating the brilliant pioneer work done by your Scientific men. That work has always been marked by subtlety and keen discrimination. We are proud to have the opportunity of toasting Italy, the Mother of Scientific Societies, and the Scientific Societies of Italy."

Prof. Raffaello Nasini, who responded on behalf of the Associazione Italiana di Chimica and Kindred Societies, stated that he was very pleased to have the opportunity of thanking the Ceramic Society, not only for their invitation for that evening, but for the benefit which he thought their visit was doing to the country. He regarded The Ceramic Society as one of the best examples of the correlation of scientific and industrial research work. In stating that, he made further references to the friendship between England and Italy.

Prof. Nasini continued: "Sir William Jones has already told us, of the development of the Ceramic Society; how it was formed a quarter of a century ago; how the membership has increased until it is now approaching one thousand; and of the work which its members have done for the various industries concerned. The members of the Society have, since the war, visited France and Sweden, and now many of them are here in Italy, where I assure you, you are most heartily welcome. During your sojourn you have visited some of our works, but you may also be certain that, had there been time for you to visit those other works which were omitted from your itinerary, your welcome there would have been quite as hearty.

Italy may not be one of the largest producers of the manufactures in which you are most interested, yet I venture to think that what we have shown you has aroused some considerable degree of interest.

The Etruscans were amongst the earliest pottery in the world and we hope that our countrymen still maintain the traditions of their early ancestors. I am not particularly interested in pottery manufacture myself, but from my connection with the production of boric acid at Larderello I feel that I collaborate with you to a considerable extent. Boric acid and similar compounds of boron are used in many glazes, and for ordinary purposes pottery without a glaze is like a man without clothes on a wet day.

If not perhaps in Roman times, yet at more recent dates the friendship between England and Italy has often been great. The connection between the two countries so far as ceramic work is concerned may not have been so obvious until modern times. Nevertheless one link between England and Italy was forged in 1844 by Edward Wood who was one of the first to indicate the use of boric acid in glazes. He visited the Soffioni at Larderello in that year. So far as relationship between the two countries is concerned, I may affirm that the feelings of all Italians for England are as full of friendship and gratitude as they were in the days when your countrymen helped us to gain our national unity. I therefore have very great pleasure in asking my Italian friends and colleagues to drink to the health and prosperity of the Ceramic Society."

Mr. J. Holland briefly responded.

Sir William Jones, in proposing the toast of The Guests, said: "Since our arrival in this beautiful country our guests of this evening have been our hosts during most of our stay, and we are very much indebted to our industrial and scientific friends for their hospitality and their kindness.

The chief object of scientific research is to assist industry and the full results of such research can only be measured in industry by the improvement of the general conditions of mankind throughout the world. We ourselves have seen one very notable instance of scientific discovery during our visit to Larderello, where the

forces of nature have been harnessed in a most useful manner and have developed power, not only for Larderello, but for all the surrounding districts. Another notable instance in Italy of the application of scientific research is to be seen in the hydro-electric plant of southern Ita.y, where we have another example of the harnessing of the forces of nature. The full benefit of scientific discovery in industrial progress is only obtained by the application of economics and it is a duty of the State to see that such application duly occurs.

I should like to express my great appreciation of, and great admiration for, the way in which the laws of economics have been applied by the present Italian Government. Italy suffers from the lack of raw materials of first grade importance which are necessary for the development of any country, and I think it is very much to the credit of the Italian Government to have developed the manufacture and intensified industry in the face of very considerable difficulties. Two of our guests, Prince Ginori Conti and Commendatore Crocco are to be congratulated on the part they have played in raising the commercial status of Italy and the world. The exports of Italy have increased, the administrative expenses have decreased without the loss of efficiency, and the whole position generally may be stated to have improved very considerably.

Speaking as friends of Italy, we have every hope that the latter country will pursue the high road to prosperity, and if we can assist them in any way in so doing, we shall grudge nothing which may be for their benefit."

Commendatore G. A. Crocco, Director General of Industry in the Ministry of National Economy, responded : "On behalf of the Italian Government I wish to thank you for your presence here to-night. In particular we wish to express our indebtedness to Sir William Jones, who is, perhaps more able than others to appreciate our war efforts.

You have seen our Art, our Trade, and our Industry, and I think I may say that Italy at the present time is endeavouring to the utmost of her power to maintain her traditions in these several ways. It may be a matter of regret that our present productions do not appear to equal our master pieces of the 15th Century. The old productions have been plowed over to a very large extent by modern methods and modern industrial science. The works of Della Robia and other artists are now being replaced by articles of more obvious utility ; for example, electric insulators. Nevertheless, we may still say that, so far as the ceramic industry is concerned, there is very considerable scope for the application of both science and art, and in these two there is a welcome *rapprochement* between Italy and England. In conclusion, I wish to thank Sir William Jones for proposing this toast, and the members of the Ceramic Society for the way in which they have honoured it."

Mr. J. Burton, in proposing the toast of "Our Guests," remarked that our hosts of yesterday were the guests of to-day. He commented on the feelings engendered by the kindness and courtesy of our reception in Italy and suggested that if we were not English, the only other thing we could wish for was to be Italian. Dr. Mellor had referred to the influence of Italy on the scientific world. Science might be universally understood, but the arts in general were of a more national nature. In indicating the influence of the art of one country on another he referred to the inspiration of Italian art on English and mentioned the part played by several great Italian artists in the development of ceramics. In Italy, the ceramic art had attained a high standard in the days when in England only the peasant pottery was being produced and in this way Italy had led the way to our country. Mr. Burton briefly referred to our great indebtedness to those Italians who had assisted us during our visit and to the smoothness with which all the arrangements had been carried out. Signor M. P. Piermattei, Prof. Randone, Signor Giampiccoli and Signor Verzocchi duly responded.

On the afternoon of Wednesday, May 14th, the members were received by the Italian Chemical Society in the rooms of the Reale Accademia dei Lincei at the Pallazo Corsini. Prof. Volterra, President of the Accademia dei Lincei, welcomed the members in the name of the latter Society. It may be pointed out that this Society is the Italian equivalent to the Royal Society of London. Mr. J. Holland thanked Prof. Volterra for his reception and then took the Chair for the Ordinary Meeting of the Refractory Section of the Ceramic Society. At this meeting the following papers were read:

Mr. W. J. Rees:	"The Influence of Phosphoric Acid and Phosphates on the rate of Inversion of Quartz in Silica Brick Manufacture."
Prof. J. W. Cobb and Mr. Houldsworth:	"The Behaviour of Clays, Bauxites, etc., on Heating." Part III.
Dr. J. W. Mellor and Dr. A. Scott:	"The Effect of Heat on Kaolinite." Part I.
Dr. G. Shearer:	"Results of an X-Ray Investigation of the Crystalline Structure of China Clays, etc."
Prof. O. Rebuffat:	"Synthesis and Industrial Manufacture of Sillimanite."

An account of the papers and the discussions is given elsewhere.

The remainder of the time in Rome was spent in sight-seeing.

On Thursday, May 15th, the members left Rome in the morning for Pisa, which was reached about 4-0 o'clock in the afternoon. An opportunity was taken by most of the party to visit the Leaning Tower, the Cathedral and the Baptistry. On the following morning

the party drove to the works of the Societá Lavelli, probably the largest refractory works in Italy. They were met by Signor Lavelli, who conducted them over the works, especially the part dealing with the manufacture of magnesite refractories. The same afternoon the members left Pisa for Genoa, which was reached late in the evening. The following day was spent sight-seeing in Geno, and the homeward journey commenced on the morning of May 18th, London being reached on Monday afternoon, May 19th.

Throughout the trip the members of the party were very much indebted to several Italian friends for their kindness in interpreting on many occasions, and in showing them round various museums and so forth. Amongst these may be mentioned Signor Verzocchi of Milan, whose services were invaluable during the early part of the journey, and also at the Ceramic Society's Dinner; Signor Piermattei and Miss Johnson, who conducted the party round the museum in Rome and also acted as interpreters on many occasions.

A.S.

Mr. STEPHEN HAWTHORN.

THE death of Mr. Stephen Hawthorn, on the 20th January, 1925, at the age of 56, removed a well-known personality from the business life of the Potteries district. Born at Burslem, where his father was an earthenware Manufacturer, Mr. Hawthorn eventually applied his energies and talents in the same field of enterprise. He became associated with Mr. James Boulton, of Wolstanton, in the establishment of the Pearl Pottery, Ltd., the Diamond Pottery, Ltd., and Clementsons (Potters' Millers), Ltd., all located in Hanley. Mr. Hawthorn was Managing Director of these firms, and was a keen and very active business man, his genial character securing him a high degree of popularity. Until a breakdown occurred a few months ago, he enjoyed robust health. As a member of the Ceramic Society, he joined in several of that Society's continental excursions.

Outside his business activities, Mr. Hawthorn was connected with the Masonic fraternity as a member of Lodges at Congleton and Macclesfield, and ranked as a Past Master of the first-named of these. He was also an ardent golfer, serving for some time as captain of the Congleton Golf Club.

The interment, which took place in the family vault at Burslem Cemetery, on the 24th January, after a special service at Mossley Church, Congleton, was attended by a numerous gathering of relatives and friends—a striking testimony to the esteem in which the deceased gentleman was held in divers circles. J.A.A.

Mr. A. F. WENGER.

MR. ALBERT FRANCIS WENGER, who died on the 26th February, 1924, after attaining the patriarchal age of 86, was an outstanding figure in the business life of North Staffordshire. Born and educated at Lausanne, in Switzerland, he served his apprenticeship at an old Swiss Porcelain factory at Nyon. His next sphere of activity was at Milan, as head of the technical department of Jules Richard & Co. In 1862, he was sent to the International Exhibition in London, and found an opportunity to visit the Potteries district of Staffordshire. A few years later, he left Milan with the intention of going to the United States to make felspathic porcelain, but on reaching this country, he changed his plans, and decided to settle in North Staffordshire, where he commenced as a modeller and designer. He became associated with the late Mr. William Boulton, of Burslem, in devising sundry patents for improved potters' machinery. He soon took up the supply of colours and other potters' materials, later extending his operations to meet requirements for glazed bricks, glass, and enamels for metals. Mr. Wenger acquired the colour-making business of T. Brougham (established at Burslem, in 1820), and in course of time absorbed other firms, including the chemical business of John Jones (founded at Stoke in 1840).

Commencing his business at Cobridge about 1812, Mr. Wenger soon removed it to Hanley (Parker Street), where it was centred for many years, until in 1900 the newly erected works at Etruria were occupied, the history of the firm being throughout one of continued progress.

Mr. Wenger travelled much in connection with his business, repeatedly visiting the chief trading countries of Europe. He was an accomplished artist, and for some years was an enthusiastic member of the Sketching Section of the North Staffordshire Field Club. Though one of the oldest Freemasons in Staffordshire, he does not appear to have ever taken office. Nor did he seek prominence in public life. He was, however, a member of "Ye Ancient Corporation of Hanley," and a member of the North Staffordshire Chamber of Commerce.

Mr Wenger joined the Ceramic Society at an early period, though advancing years, no doubt, contributed towards preventing him from taking any very active part. J.A.A.

I.—The Grading of Silica Bricks.

By P. B. Robinson, M.Met. and W. J. Rees, B.Sc., F.I.C.

THROUGH the courtesy of several manufacturers of silica bricks, the authors were able to investigate the properties of bricks in the "green" state and of burned bricks from the same batch. The purpose of the investigation was to discover the types of grading which resulted from the ordinary process of grading as practised by these makers, and, if possible, to discover points essential to the production of a mechanically strong, even-textured, sound brick. All the bricks examined were very similar in chemical composition, and were made from rocks containing 95-98 per cent. silica to which a 1·5 to 2 per cent. lime bond was added. With the possible exception of one case in which the iron content was rather high, the bricks are considered for the purpose of this investigation as being chemically similar.

Experimental Methods.

Mechanical Analysis. The green bricks were crushed gently in a mortar and well stirred with a pestle in order to separate the individual grains of which the brick was composed, care being taken that no further crushing of the material took place. The crushed material was then sieved through wire sieves, each batch resting on any sieve being returned to the mortar and alternately stirred and sieved until it was clean of any adhering smaller grains. This was done for the following sieves: 10, 20, 30, 40, 50, 60, 80 and 90 meshes to the inch. The 70 and the 100 mesh to the inch sieves available were found, on standardising, to be out of harmony with the others of the series, and therefore, were neglected.

The material passing through a 90 mesh sieve was further separated by elutriation into 4 grades corresponding to the following sizes :—

grade *a.*	$>\cdot 1$	mm.
b.	·05–·1	mm.
c.	·01–·05	mm.
d.	$<\cdot 01$	mm.

The method was as follows (described by Boswell, *Glass Sand*, and Mellor): 10 gms. of the material were shaken up with water in a tall glass cylinder and allowed to settle for a definite time, after which the turbid water was decanted off and the process repeated until the water was quite clear; then the same was repeated for the next

grade. The details of the heights of the column of water and the times, are as follows :—

27 cms. of water, allow to settle 30 mins. when decanted retains grade *d*
12 ,, ,, ,, ,, 1 ,, ,, ,, ,, ,, *c*
14 ,, ,, ,, ,, 20 secs. ,, ,, ,, ,, ,, *b*
remainder is grade 2.

The grades thus separated were allowed to settle, the water decanted and the graded material slowly sieved.

The grades obtained were weighed, and the volume approximately measured by allowing the material to flow in two thin streams and settle without pressure in a graduated glass cylinder. Some of the grades did not pack so well as others and this fact was noted, and the "Packing Density" of each grade determined by dividing the weight of the grade by the volume it occupied in the graduated cylinder.

Visual Examination. Each large grade was examined visually, special attention being paid to its angularity. The size of the largest particles resting on the 10 mesh sieve was measured.

Microscopic Examination. The graded materials were examined under a microscope and photographs taken at 20 magnifications of most of the grades. Those obtained by elutriation were photographed by transmitted light, and the remainder by reflected light. From these the nature of the grains with special reference to their angularity was noted, and the presence of minerals other than silica. The average size of grain in each grade was determined by actual measurement from the photomicrographs.

Chemical Examination. This was confined to one of the graded series only, time not permitting of the examination of the remainder. One gram of each grade finely ground was treated with hydrofluoric acid in a platinum crucible, evaporated to dryness, and ignited to redness. The crucible, after cooling in a dessicator, was weighed, and the increase in weight noted.

Examination of the Burned Bricks. The powder specific gravity of the burned bricks and the bulk density were determined by the usual methods, and the porosity calculated from these values, using the formula :

$$\text{Porosity} = 100 - \frac{\text{bulk density}}{\text{powder sp. gr.}}$$

The crushing strength of the bricks was determined by placing each brick on end in a Buckton machine, fitted for compression test, and applying a steadily increasing load till failure occurred.

Results.

Visual Analysis : In order that the results of the mechanical analysis may better be appreciated, the results of the visual analysis of the largest grade (resting on 10 mesh sieve), and a description

of the original rock used in each case, will be considered. The figures given denoting angularity, are arrived at from consideration of the relative angularity of all the particles of the brick, the number 7 being allotted to the most angular series, and diminishing numbers to the remainder according to their apparent relative angularity.

A. Very uniform collection of dark grey grains, largest 7 mm. in greatest dimension. Original rock a Sheffield ganister. Angularity 5.

B. Many large pieces, up to 20 mm., altogether much coarser than any other brick examined. Material uniform dark grey colour. Durham ganister. Angularity 3.

C. Odd pieces up to 12 mm., but very few of these, the majority being less than 7 mm. Material grey, uniform in colour. Sheffield ganister. Angularity 6.

D. Mixed collection of grains, some white, some red, vitreous looking, most light coloured, but some grey. Original rock mixture of Welsh quartzite and Sheffield ganister. Angularity 5. Largest piece 6 mm.

E. Large grades very friable, some pieces 15 mm., but these broke down on handling. Even dropping into water was sufficient to break down these pieces into a light grey sand. Large pieces, formed by accumulation of very loosely cemented sand not themselves very angular, and sand grains fairly rounded. Some mica spangles visible. Original rock a friable, slightly micaceous, but highly siliceous sandstone from coal measures. Angularity 1.

F. Mixed collection of very angular fragments, in general reddish tinge, very uniform in size, 5–8 mm., very few larger than 8 mm., and none larger than 10 mm. About one-third dark red vitreous looking, remainder practically all white with a faint pink tinge. Original material highly siliceous pebbles from Bunter formations. Angularity 7.

G. This material is dry crushed, not so angular as previous ganisters. Average size 3-5 mm., with very occasional pieces larger than 5 mm. Fragments show iron staining. Original rock a Weardale ganister. Angularity 2.

Microscopic Examination. Microphotographs of two of the series of the graded materials are here reproduced (Fig. 1). The principal point shown by these photographs is the angularity of the grains. In those grains derived from ganisters, angularity of grain is a feature throughout the series. Such persistent angularity of grain can only be associated with a rock composed of grains originally highly angular, closely backed or strongly cemented, thus giving a hard and compact rock mass. The series *F*, from crushed pebbles from the Bunter formations, are even more angular than the ganister series.

The series *G* from a dry crushed Weardale quartzite is not so

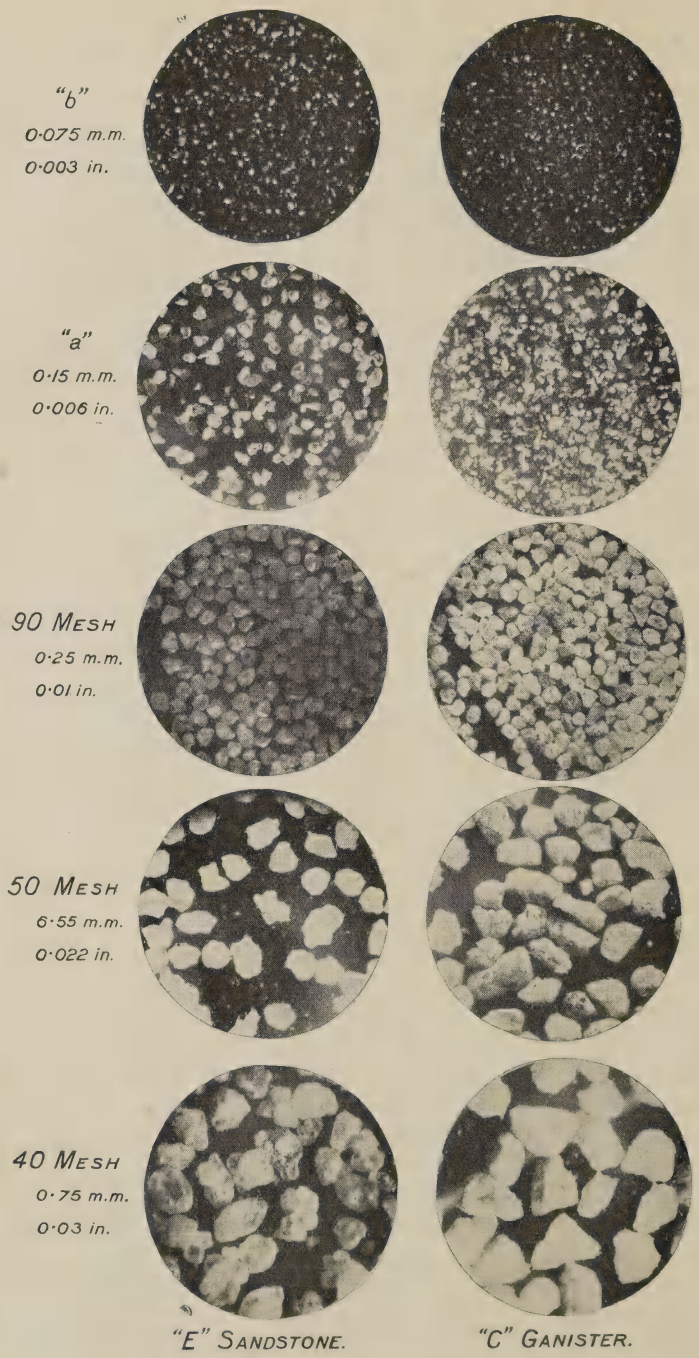


Fig. 1.
Microphotographs of Graded Materials. (x 5).

highly angular, except in the small grades,—the large grades have a decidedly rounded appearance. This would appear to be due to the method of crushing, as the 90 grade is highly angular, and, as will be seen from later considerations, this 90 grade probably represents what is very nearly the original grain size of the rock. It might, however, also be partly due to the nature of the cementing material, as the rock is not so hard as the Sheffield ganisters, and contains rather a higher percentage of Fe_2O_3. In all the materials, the grade *b* is probably the most angular of the series. This is due to the fact that the grain size of all of them lies between the 90 and the *a* grade,—*i.e.*, about ·2 mm., and thus the grade *b* must consist of quartz grains which are actually crushed while the larger grades consist of aggregations of whole grains of quartz.

The series *E* derived from a friable sandstone crushed dry, is interesting as emphasising, in an entirely different type of rock, the points made above. The series down to the 90 grade is very rounded and in many places clearly shows the composite nature of the crushed pieces. The *a* grade in this case has the outstanding angularity which in the previous cases was the property of the *b* grade, showing that in this *a* grade, crushing of the original grains of the rock has commenced, although in the photograph of this grade under polarised light, several of the larger pieces are clearly seen to be of a composite nature. In this case, the 90 grade probably represents the original grains of the rock, and this also is borne out by a study of the grading curve obtained from this material. The quartz is very transparent in this rock and the rounded grains are very loosely cemented together, the rock crumbling at a touch.

Chemical Analysis. The amount of impurity present in each grade was estimated roughly by the action of hydrofluoric acid on 1 gm. of the finely ground grade and subsequent ignition. The results are shown in Table IV., the material used being from the brick *A*. It is seen that there is considerable variation in the concentration of the impurities, which, in this case, rise to a maximum in the 60 grade and subsequently diminish through the finer grades. This variation may be due to either or both of two causes: (*a*) concentration of lime or lime silicates formed during the drying process; (*b*) concentration of heavy minerals. This phase of the work has not yet been followed further.

Mechanical Analysis. The results of this are shown in Table I in which the percentage by weight and volume of each grade, together with the packing density are shown. With the exception of the brick *E*, the packing density of the grades falls to the 30 grade, after which it rises, there being considerable diversity in the density of packing of the smaller grades, a diversity which cannot be explained merely on the ground of their varying angularity, as no

TABLE I.—SHOWING RESULTS OF MECHANICAL ANALYSIS OF GREEN BRICKS

Screen number	Average size of grain		*A*			*B*			*C*			*D*			*E*			*F*			*G*		
resting on	mm.	inches	Wt. %	Vol. %	Pkg. dens.	Wt. %	Vol. %	Pkg. dens.	Wt. %	Vol. %	Pkg. dens.	Wt. %	Vol. %	Pkg. dens.	Wt. %	Vol. %	Pkg. dens.	Wt. %	Vol. %	Pkg. dens.	Wt. %	Vol. %	Pkg. dens.
10			14·2	13·6	1·44	35·5	32·7	1·39	20·5	19·0	1·40	5·5	4·9	1·39	3·4	4·0	1·15	15·4	14·0	1·42	17·2	16·6	1·44
20	2·25	·089	19·0	19·2	1·36	11·2	11·3	1·27	17·6	18·0	1·30	16·8	15·4	1·35	3·3	4·2	1·06	20·5	19·0	1·38	14·1	15·2	1·30
30	1·25	·049	7·7	8·05	1·31	3·8	4·3	1·14	5·55	6·2	1·19	9·1	8·3	1·29	3·8	4·6	1·12	10·4	10·0	1·34	5·4	0·2	1·21
40	·75	·029	3·1	3·16	1·35	1·7	1·7	1·31	2·75	3·35	1·09	3·9	3·8	1·29	6·3	6·6	1·26	5·4	5·4	1·28	2·7	2·8	1·30
50	·55	·022	2·8	2·8	1·37	1·9	1·95	1·23	1·5	1·7	1·17	3·65	3·5	1·29	9·5	9·5	1·33	3·5	3·5	1·32	3·6	3·8	1·32
60	·45	·018	2·45	2·4	1·41	1·4	1·35	1·29	1·6	1·8	1·27	2·4	2·5	1·19	9·5	9·3	1·37	2·6	2·6	1·31	1·9	1·9	1·36
80	·35	·014	4·5	4·5	1·37	3·5	3·5	1·27	3·0	3·4	1·18	7·2	6·8	1·29	30·0	2·92	1·38	5·9	5·8	1·31	8·4	8·6	1·36
90	·25	·01	6·6	6·4	1·42	8·9	8·6	1·32	4·5	4·5	1·29	12·2	11·4	1·32	19·7	18·9	1·40	6·2	6·2	1·30	9·7	10·0	1·34
90+			39·8	39·9	1·37	32·1	34·8	1·18	43·0	42·0	1·35	39·3	42·8	1·14	14·3	13·5	1·42	30·4	33·6	1·16	37·0	34·8	1·49
a	·15	·006	28·1			21·0			32·0			28·0			11·9			15·1			23·0		
b	·075	·003	6·4			5·1			3·65			4·0			1·2			11·5			9·7		
c	·025	·001	4·2			5·2			·65			6·7			·83			2·73			3·6		
d	·01	·0004	·2			·3			·35			·3			6·13			·45			·7		

connection can be traced between the two. In the case of the rock *E*, the density of packing rises regularly from a low value for the large grades to a comparatively high value for the small grades, a rise which follows out well the increasing angularity of these grades from large to small. In the table, the average size of grain resting on each sieve is given ; this was obtained by actual measurement of the photographs.

One feature of the results shown is the small amounts of what may be termed the "Medium" grades (40-90 sieve), present in all cases except the soft rock *E*. With this exception, the grading in all the bricks examined shows points of similarity which are more clearly brought out in the summarised Table II. In this table, the grades are put into 3 groups, "Coarse," down to 30 sieve, "Medium," 30-90 sieve, and "Fines." passing a 90 sieve. It is

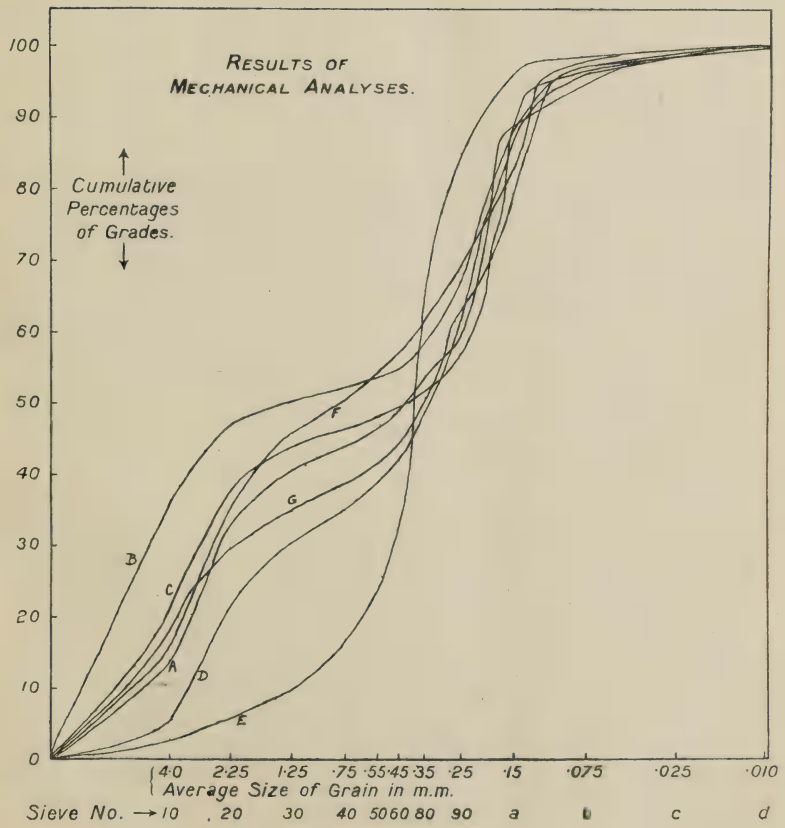


Fig. 2.

seen that the "Coarse" grade occupies about 40 per cent. of the brick and the "Fine" grade also about 40 per cent., while the "Medium" grade occupies the remaining 20 per cent. The functions of these different groups will be considered later, in discussing the mechanical strengths of the bricks.

TABLE II.—SUMMARY OF GRADING.

Showing Percentages by Weight of Coarse, Medium and Fine Material in the Bricks.

	A	*B*	*C*	*D*	*E*	*F*	*G*
Coarse 10, 20, 30 sieve ..	42	50	42	30	11	45	37
Medium passing 30 sieve retained by 90 sieve ..	18	18	15	30	74	25	26
Fine through 90 sieve..	40	32	43	40	15	30	37

In table III., the results are shown in a cumulative manner—that is, the percentage of material resting on any sieve is shown, together with the grain size of the smallest grains resting on this sieve. These results are shown graphically in Fig. 2. The horizontal scale is proportional to the logarithms of the grain diameters. Horizontality in any part of the curve means the absence of the grain-size corresponding to the distance to which such horizontality extends. Verticality in the graph indicates a considerable percentage of the grain-size corresponding to the position of the vertical portion.

TABLE III.—RESULTS OF MECHANICAL ANALYSIS.

Arranged in a Cumulative Manner, showing Percentages by Weight Retained by any Sieve.

Screen No. mesh.	Average size of grains in mm.	*A*	*B*	*C*	*D*	*E*	*F*	*G*
10	4·0	14·2	35·5	20·5	5·5	3·4	15·4	17·2
20	2·25	33·2	46·7	38·1	22·3	6·7	35·9	31·3
30	1·25	40·9	50·5	43·6	31·4	10·5	46·1	35·7
40	·75	44·0	52·2	46·4	35·3	16·8	51·5	38·4
50	·55	46·8	54·1	47·9	39·8	26·3	55·0	42·0
60	·45	49·25	55·5	49·5	41·9	35·8	57·6	43·9
80	·35	53·75	59·0	52·5	49·0	65·8	63·5	52·3
90	·25	60·35	67·9	57·0	61·2	85·5	69·7	62·0
a	·15	88·45	88·9	89·0	89·2	97·5	84·8	85·0
b	·075	94·85	94·0	92·65	93·2	98·7	96·3	94·7
c	·025	99·0	99·15	99·3	99·9	99·5	99·0	98·3
d	·010	99·2	99·45	99·7	100·2	99·7	99·5	99·0

Properties of the Burned Bricks. In table V. the bricks are arranged in order of mechanical strength, and the properties of the burned bricks are shown, together with those properties of the green brick which appear to affect the crushing strength of the final product. The brick *E* is not included in this table, as unfortunately the burned brick from the same batch as the green one examined was not available. All other bricks, however, made from this material examined subsequently were much weaker than the weakest in the table shown, so that, in all probability, the brick *E* would have been at the bottom of the table. The bricks partake of the nature of the rock from which they are made and are very friable and soft.

TABLE IV.

Retained by sieve	Wgt. of residue from 1 gm.
10	·024 gm.
20	·035
30	·032
40	·049
50	·054
60	·128
80	·030
90	·025
+	·055

TABLE V.—PROPERTIES OF BURNT BRICKS, IN ORDER OF CRUSHING STRENGTH.

Brick	Mech. strength tons/in².	Bulk density	Powder density	Porosity %	Fines %	Coarse %	Largest grains. mm.	Angularity
C	1·41	1·79	2·455	27·0	43	42	7	6
F	1·25	1·78	2·39	25·5	30	45	6	7
A	·83	1·79	2·50	28·4	40	42	5	5
D	·80	1·80	2·52	28·7	40	30	6	5
G	·71	1·86	2·42	23·2	37	37	4	2
B	·62	1·83	2·52	27·4	32	50	12	3

Consideration of TableV. brings out the following points :—

Bulk Density. In general, the bulk density of the strongest bricks is lower than that of the weaker. The bulk density depends originally on the grading of the rock, type of rock, and method of moulding, but it also depends on the amount of burning to which the brick has been subjected, burning to a higher temperature tending to reduce the bulk density.

Powder Specific Gravity. In general, this is lower in the strongest bricks than in the weak ones, again showing that a higher burning temperature tends to strengthen the brick.

Porosity. This is calculated from the two preceding values. The porosity of a burned brick is usually about 1-2 per cent. higher

than in the green brick from which it is produced. There does not appear to be any direct relation between porosity of the brick and its mechanical strength within the limits examined.

Percentage of Fine Material (through a 90 sieve). This, in general, is about 40 per cent. although in the relatively strong brick *F* it is as low as 30 per cent.; this brick, however, has a low powder density and is made from material of high angularity, so that these two factors may counterbalance the relatively low percentage of fine material. This fine material is an important factor in the formation of a melt through which inversion of the quartz can proceed.

Percentage of Coarse Material (10, 20, 30 sieve). In the strongest bricks, this exceeds 40 per cent. Its presence is very necessary to impart strength to the brick.

Size of Largest Particles. In the strongest bricks this is of the order of 6-7 m.m. A brick with about 40 per cent. of material resting on a 30 sieve, the largest grains being about 6-7 mm., shows a well graded, uniform texture on fracture. More of this and coarser grades, as in the brick *B*, produces a weak brick.

Angularity. The figures allotted, from the grade examination, to each brick are lower for the weakest bricks. Angularity of the grains is important in promoting good packing and interlocking of the grains, and in providing the maximum properties of grain surface accessible to the action of the inversion—promoting melt.

Influence of Burning Temperature.—In order to show more clearly the effect of burning temperature on the mechanical strength of the bricks, examination of bricks made of the same material, and of the same grading, was made. These bricks were burned in works kilns to different temperatures, and the results are shown in Table VI. This table clearly shows that with increased burning temperatures, the bricks are strengthened.

TABLE VI.

EFFECT OF BURNING TEMPERATURE ON MECHANICAL STRENGTH.

Burnt to	Mechanical strength tons/in².
Cone 15	·99
16-17	1·24
20	1·39

Mechanical Strength. The crushing strength of the bricks on end, varied between 1·4 tons per sq. in to ·62 tons per sq. in. (18 to 6 tons on a 3″ brick). The strongest bricks under this test broke suddenly by shearing, but the weaker ones developed cracks in different directions and crushed in no definite way. Although silica bricks are never subjected to loads of 1 ton per sq. in. in

ordinary furnace structures, yet a high mechanical strength is important, as a strong brick is better able to resist wear and tear in handling, and retains its edges and corners. It is also important that the "clay" (or "brick batch") should be strong, so that bricks or shapes when moulded will retain their shape and not squat. In resisting this tendency to squat, the largest particles play an important part, and their size, distribution, and angularity is important.

Summary of conclusions. In conclusion, the points of practical importance in the production of a mechanically strong brick may be summarised as follows:—

(*a*) A hard, fine-grained rock, crushing into fragments of high angularity should be used.

(*b*) The grinding should be of such duration that the size of the largest particles will be of the order of 6–7 mm., with about 4 per cent. of the material retained by a 30-mesh-to-the-inch sieve. These large, angular particles give strength both to the green and the burned brick.

(*c*) If the grinding is carried out as above, the percentage of material passing a 90 mesh sieve will depend on the grain size of the rock and the strength of its bonding material. With the ganisters ordinarily used in the manufacture of silica bricks, the grain size is about ·2 mm., and when the rock is crushed so that the largest particles are 6–7 mm., rather more than 40 per cent. of the material passes through a 90 sieve. This fine material is necessary to produce compactness in the brick, and for the production of a melt which will promote the inversion of the quartz on burning.

(*d*) The bricks must be well burned. Results show that increased temperature of burning up to cone 20 increases considerably the mechanical strength of the brick.

Department of Refractory Materials,
University of Sheffield.

DISCUSSION.

Mr. C. Edwards:—I would like to ask the speaker whether in the sieving tests any attempt has been made to remove the finer fragments from the coarse by washing; because it seems to me that unless something of this sort is done, a great deal of error is likely to be introduced by the adhesion of the finer grains to the coarser ones. I am wondering whether the materials were sieved dry or washed.

Mr. P. B. Robinson:—The sieving was done entirely dry, and as each grade rested on the sieve the material was rubbed

over a little in order to get as much as possible of the fine ground stuff away.

MR. W. EMERY:—Have the investigators made any spalling tests or tests of crushing strengths at high temperatures, and if crushing tests have been made, on which face of the brick has the load been applied?

MR. W. J. REES:—The mechanical strength when hot obviously depended upon the angularity of the grain fragments. The greater the angularity of the grain, the greater the hot crushing strength of the bricks, the results being comparable throughout to the cold crushing strength.

II.—The Zenith Temperature.

By J. W. Mellor.

We are generally told that the lowest possible temperature is somewhere near -273°C., and this temperature is universally accepted as the nadir temperature, and is called the absolute zero. We are sometimes told, however, that there is no limit at the other end of the scale. With the average working temperatures of furnaces steadily rising, this seems to offer a gloomy prospect of endless troubles to future manufacturers of refractory materials. I have made a rough calculation so as to find the worst that can befall us, and it appears that the prospect is not quite so bad. There is a limit, and the manufacturer can defy the user to go beyond the limit which nature seems to have imposed.

According to the kinetic theory of gases, temperature is determined by molecular or atomic movements; and their mean velocity, V, at the absolute temperature, T, is $V = 15800\sqrt{\frac{T}{M}}$ cm. per sec.

If the postulate of the quantum radiation theory is right, and the velocity of light is the maximum speed at which material things can travel, then, since light travels at about 3×10^{10} cm. per sec. in vacuo, and since, for hydrogen, the lightest gas, $M = 1$, therefore, $3 \times 10^{10} = 1{\cdot}58 \times 10^4 \sqrt{T}$. This means that, if everything varies continuously on a rising temperature, refractory materials will never have to face a higher temperature than something less than four million million degrees absolute, or 4,000000,000000°.

III.—Tridymite and Tridymite Bricks.

By O. Rebuffat.

SINCE the publication of my preliminary note* I have followed up the argument developed therein, and have devoted my attention to certain practical applications suggested by the theory. I have carried out a number of experiments, from which I have obtained certain results of scientific value. These results I now propose to communicate. All my experiments on the transformation of quartzite into silica of low density were performed with the same multiple catalyst as was used in the preliminary tests. Reference is also made to this in the corresponding patents. The proportion of catalyst employed was throughout maintained constant below one per cent. of the transformed quartzite.

In the discussion which followed Messrs. Houldsworth and Cobb's communication to the Ceramic Society on :"The Reversible Thermal Expansion of Silica," Dr. Scott affirmed that the production of silica of low specific gravity by my process was by no means new, since tridymite had already been obtained by crystallisation from fused sodium tungstate. From my note, it is quite obvious that I was well aware of this method of the preparation of tridymite ; but it is one thing to prepare small quantities of tridymite by crystallisation from fused sodium tungstate, and quite another to transform tons of quartzite by heating at a suitable temperature in the presence of very small quantities of a catalyst.

Numerous tests, carried out on a large scale, demonstrated the fact that the transformation of quartzite takes place very rapidly even when large quantities are employed. If quickly raised to a temperature of 1,400°, coarsely powdered quartzite is completely transformed after five or six hours heating, while the remarkable increase in volume (between one-sixth and one-seventh), which accompanies the transformation, produces the agglomeration of the product. The product thus obtained has a density varying from 2·23 to 2·26 and must consequently be considered as almost pure tridymite.

Since silica bricks remain exposed for lengthy periods to a temperature of higher than 1,500° when in use, and since opinions on the behaviour of silica at this elevated temperature are not unanimous, I considered it necessary to study the behaviour of silica of low density obtained by my process at temperatures above 1,500°. I accordingly heated this product to 1,650° and 1,700° successively for several hours, and found that the density of the silica did not increase. The following figures were obtained with

*Trans. **21**, 66, 1923.

silica having a specific gravity of 2·26 (compared with water at 14°C.):

On heating at 1,650° the density was 2·26
,, ,, 1,700° ,, ,, ,, 2·23—2·24

These experiments indicate that the density remains constant up to a temperature of 1,650° and commences to decrease at 1,700° in consequence of the transformation of silica from the crystalline to the vitreous state.

The results of my work lead me to the conclusion that cristobalite is not produced by heating tridymite beyond 1,400°; and also for lower temperatures, the density of the product seems to point to the same conclusion. This is, in reality, not so contradictory to Fenner's results as might at first appear. Fenner says that cristobalite is formed, without tridymite, by prolonged heating of quartzite *alone* at a very high temperature; but, when describing other ways in which cristobalite is formed, he is not so precise, and he does not always succeed in explaining satisfactorily the process of the phenomenon.

And, indeed, considering the complex way in which cristobalite loses, or acquires, its birefringence (transformation from the α to the β form, and *vice versa*), and also its higher density, it seems more logical to assume that cristobalite represents a state of higher molecular condensation, and that, therefore, it is not absolutely essential to admit that cristobalite must be formed by heating tridymite to a temperature above 1,450°

I may add that I have not found microscopic examination of the product of any great assistance to me. It has already been observed, that, in certain positions, tridymite presents a feeble birefringence like cristobalite. Furthermore, I have not yet been able to determine the refractive index by the Becke method.

IV.—Improvements in Drying Refractories or Other Goods.

By J. Holland and W. J. Gardner.

THE Drying Stove we are about to explain was primarily invented for the purpose of drying silica bricks, although it can be used for other similar or kindred industries, where properly controlled and economic heat treatment for large quantities is requisite. In the past, the methods generally employed for drying silica bricks have been either :—

(1) Carrying off the bricks from the moulder, and placing them for drying on "drying floors" heated by direct coal firing, exhaust heat from kilns or boilers, or by raw or exhaust steam ;

(2) By placing bricks on racks, in an enclosed drying stove, which is fired overnight ;

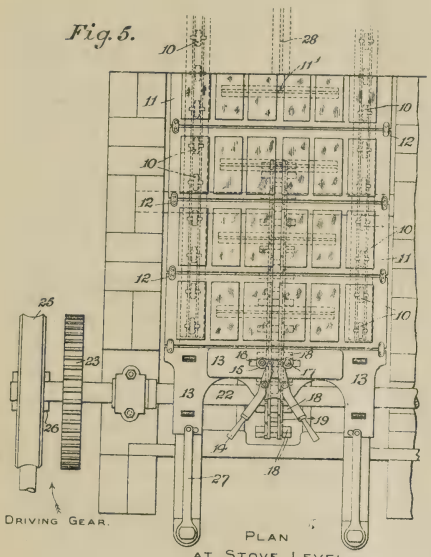
(3) By means of travelling racks passing through a tunnel dryer, the two former methods being more generally in use.

The usual drying floor and enclosed stove methods have very objectionable features, being particularly dusty in their operations, even under the best possible conditions, and necessitating work being carried on under disagreeably hot and dusty surroundings.

The recent legislation known as the "Workmens Compensation (Silicosis) Act, 1918" has vividly brought to the notice of manufacturers the desirability of evolving some scheme for drying silica bricks which would reduce to a minimum the dusty conditions of work. It was with this object particularly in view, that the authors first tackled their problem, and the result is this paper, which deals with a method of drying silica bricks by means of a stove which is heated by gases and products of combustion radiating through the floors and side walls, whilst the goods are slowly transported through the stove on wrought iron plates running over a tram-way, the machinery for this motion being fixed at the front of the stove and worked by means of a worm shaft connected with the main drive of the mill.

A chamber, or chambers, of convenient size (1, Fig. 1), in this case 3 ft. wide and 60 ft. long—called the "hot zone"—is fitted with damper plates at either end, which, being balance-weighted, are lowered or raised at will to clear any size of bricks or blocks required to pass through the stove. Beneath the front of the drying chamber from end to end, extends a flue (4, Fig. 1) connected with a suitable furnace (5, Fig. 1) at the front of the stove, or the hot

Fig. 5.



PLAN
AT STOVE LEVEL.

Fig. 6.

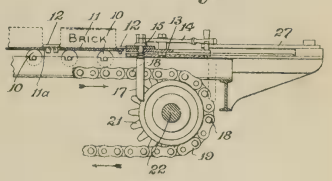
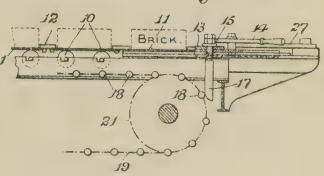
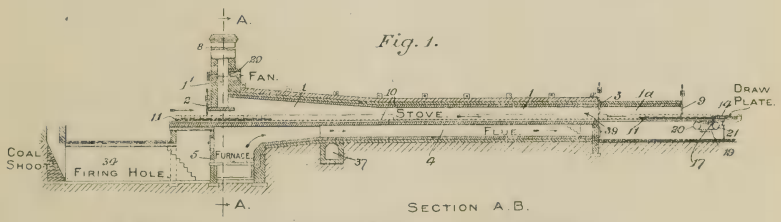


Fig. 7.



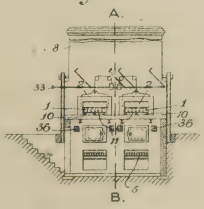
DETAILS OF DRAW PLATE.

Fig. 1.



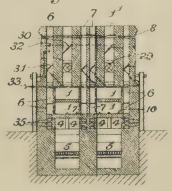
SECTION A.B.

Fig. 2.



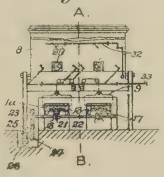
FEEDING END.

Fig. 3.



SECTION. A.A.

Fig. 4.



DRAWING END.

gases may be supplied from the burning or burnt off kilns by the flues (37, Fig. 1) or from any other convenient source. At the rear end of the chamber the flue breaks off, right and left, into, or communicating with, flues (6 and 7, Fig. 3), disposed on each side of the chamber, which lead to the chimney stack over the front (8, Figs. 1 and 3). The floor and side walls of the drying chamber are composed of slabs made of refractory materials.

At the rear end of the chamber, and forming a continuation thereof, is a cooling chamber called the "cold zone" (1*a*, Fig. 1), of suitable length—in this case 10 ft.—which is cut off from the drying chamber by a baffle or damper (3, Fig. 1).

On the floor of the drying chamber and cooling chamber (1 and 1*a*, Fig. 1), are two parallel steel tracks containing steel rollers (10, Fig. 2), suitably spaced. This roller track extends a convenient distance to the exterior of the "feeding" and "delivery" ends as shown.

The goods to be dried are placed on plates (11, Figs. 1 and 5), having elongated holes at either corner, to enable one plate to be coupled to another by means of special pins (12, Fig. 5), having depending lugs, the lower ends of which are interned. On the plates being pulled upon to traverse them along the rollers, the interned portions engage below the edges of the opening in the plates and prevent the pins rising out of engagement.

To traverse the goods through the stove a draw-plate is provided (13, Figs. 5 and 6), which is linked or connected to the front plate of the built-up tray, with a similar pin arrangement to those previously described, and attached to which are two steel depending fingers (17, Figs. 1 and 6) bolted to the plate and fitted with a spring cushion.

The driving shaft (22, Fig. 6), is fitted with a gear wheel (21, Fig. 6), round which is a steel chain working over a countershaft 2 or 3 feet away. On this chain are attached horizontal lugs (18, Fig. 7), and as they move forward, the vertical depending fingers (17, Fig. 7), are interposed by means of a lever (14, Fig. 7), as shown in Fig. 5, contact being thereby made with the horizontal pins on the moving chain. The draw plate and attached brick plates are drawn down at a suitably low speed, determined by the ratio of the gearing. As the chain passes round a chain wheel (21, Fig. 6), the pins which have been in engagement with the fingers (17, Fig. 7), pass clear of the said fingers and leave the table automatically at rest. The hand levers (14, Fig. 7), are then operated to slide the blocks (15, Fig. 7) outwardly along the slot (16, Fig. 5), thereby placing the depending fingers clear of the horizontal pins (18, Figs. 6 and 7) on the chain. The goods are then removed from the forward plate, and after disconnecting or removing the small interned pins, this plate is cleared and sent back to the front for re-use, the draw-plate being pushed forward on its roller bed, connected up to the next plate, and again put into gear.

Levers or arms (27, Figs. 6 and 7), pivoted to extensions of the supporting frame work and resting at their free ends on the upper surface of the draw plates (13, Fig. 5), serve to hold the latter down on its supports during its sliding movements.

The brick plates (11, Fig. 5) are stiffened on their under side with a length of tee-iron to obviate any lateral displacement during their traverse through the stove, which is provided on its under side with a notch or recess (11, Fig. 5), to pass over a central longitudinal guide rib (28, Fig. 5). As each plate (11) is linked on to the built-up table at the feeding end of the stove, it engages over this centre rib and slides along the same as the plate is drawn forward, thereby keeping it in position.

As the goods dry in their transit through the stove by radiation of the heat through the walls and floor, the contained moisture is driven off in the form of vapour and steam, and passes off up the chimney (1, Fig. 1).

A fan (29, Fig. 3) is preferably located in this uptake from each drying chamber, to assist in removing the steam and vapour, and drawing in air for cooling purposes at the delivery end, and a damper is provided to regulate the draft or close the upper part entirely when the fan is in operation. There are also dampers of any suitable design or arrangement to each uptake outlet of the side flues (6 and 7, Fig. 3) to be operated at will.

Along each side of the main flue under the drying chamber, are suitable passages (35, Fig. 3), for "secondary" air supply, which is finally admitted into the drying chamber—after pre-heating—immediately in front of the plate (3, Fig. 1), which divides the drying and cooling chambers.

The entrances to these flues (36, Fig. 2), at the front of the stove in the fire-hole, are fitted with sliding grates or other means to enable the quantity of air to be regulated.

Cold air passing over the hot bricks in the cooling zone mixes with the secondary air as it enters the chamber, and assists in taking off the steam and drying the goods. This provision guards against the heated goods being suddenly subjected to cold air as they leave the drying chamber, thus obviating trouble which might arise through sudden contraction and cracking; and if an even temperature is maintained, under such conditions the bricks will be delivered at the drawing end quite strong, dry and cool, ready for setting.

It is better that bricks are not left standing over the furnaces if the stove is stopped for other than meal hours; rather should the plates be drawn down until the bricks are clear. This avoids too rapid drying, which has a tendency to make the bricks "punky" by spoiling the setting properties of the lime.

The small roller bearings are lubricated with plumbago. At least once every three months the plates should be drawn out, the stove cleaned and these bearings re-lubricated; at the same

time the furnace flues—which are quite accessible by means of soot doors—may be cleaned also.

The stoves are fitted with suitable pyrometers, temperature and draft recording instruments, etc., to assist in regulating the temperature and draft required for the operations.

This stove of two chambers, detailed in the accompanying drawings, and as now in operation at the works of The Meltham Silica Fire-Brick Co., Ltd., is capable of drying 5,000 bricks per shift of nine hours, at a temperature of about 100°C. at the centre of the stove above the bricks. This system of drying improves the conditions for the employees as compared with the old system of "carrying off" from the moulding benches and placing on hot flats.

Placed under suitable cover, with proper ventilating arrangements, a more cool atmosphere and less dusty conditions for working can be maintained. In addition to this, the requirements of the Home Office, particularly with reference to silica dust, as previously stated, are more easily and effectively maintained.

A very much smaller ground area is required for a given output of bricks, thereby reducing plant expenditure so far as land is concerned; and from the above figures it will be seen that much is saved in time. In addition, the better conditions and easier facilities afforded by the stove arrangement for drying bricks encourage a higher quality of goods.

DISCUSSION.

Dr. Cronshaw:—Mr. Gardner and his colleague have undoubtedly evolved a very clever design for the drying of refractory goods. The only criticism that I can make is that it may possibly be a little too elaborate, and perhaps rather expensive to erect and to run. But perhaps Mr. Gardner may care to enlighten us on this point.

I should like to ask whether the plates on which the bricks are placed are perforated. If they are not, would there be any objection to having them perforated? The bricks are put on, as I understand it, one thickness deep. Would there be any objection to having them stacked? If there is some objection to this would it not probably be more efficient to run several tunnels heated by a central heating system instead of having independent tunnels heated up by independent heating systems? Again, has any provision been made to maintain a balance as regards supply and demand? This is an extremely important point in connection with drying tunnels of this description. Most of the disappointments which arise from the running of drying tunnels are, I think, due to this source. It is left to the mercy of the person who is running the kiln, and he does not always take the trouble to see that throughout the working period the kiln or tunnel is actually

full of bricks. In times of excessive demand bricks are taken off quicker than they are supplied. In all designs there ought to be some provision made for rendering a tunnel fool-proof in this respect. In connection with the drying tunnel now under consideration, I would like to know whether this has been arranged or could be arranged. Further, would it be too much to ask Mr. Gardner if he could supply us with some idea of the distribution of temperature and humidity throughout the tunnel? It is stated that at the charging end, or near the charging end, there is almost 100 per cent. humidity, and in this respect the tunnel resembles such types of dryer as the "Proctor." But has any actual measurement been made? Although the bricks enter wet, of course, it does not follow, by any means, that the atmosphere at this end of the dryer is completely saturated. I presume there is a fairly high temperature at this end of the tunnel, since with increase of temperature, the relative humidity is lowered; and in view of the fact that there is a considerable space above the single layer of bricks having a high temperature and a very rapid air movement, one is apt to be rather sceptical about this claim for a high humidity. In conjunction with the distribution of heat and humidity we should probably all be interested to know what is the velocity of the air throughout the tunnel. These are the main points that I would like to comment upon. If it will not strain Mr. Gardner's generosity too much, I would like to ask him what, in rough figures, would be the actual consumption of fuel per thousand bricks produced?

Col. C. W. Thomas:—I would like to congratulate Messrs. Holland and Gardner on their paper. In the first place, the large scale diagrams that have been prepared, have made the paper one which it is quite easy to follow, and secondly, from the very good series of photographs of the plant in actual work, we have been able to get an excellent idea of the scheme. My experience has sometimes been, in listening to papers, that I have had to exercise my imagination almost to the point of undue strain, in order to get a fair idea of the procedure. In this case there has been no difficulty whatever, and I think that the paper that we are now considering may serve as a model in this respect. I notice that the authors claim very much greater efficiency, from the point of view of floor area required, than is the case with the ordinary drying floor. My experience of drying floors, as applied to ordinary firebrick is that the best you can hope to get is an output of about four $9 \times 4\frac{1}{2} \times 2''$ bricks, every 24 hours, per square foot of floor surface, and, roughly speaking, the figures that Mr. Gardner gives are somewhere about six times this output, so that I think the claim he makes is justified. The one point which rather troubles me was brought up by Dr. Cronshaw. Mr. Gardner speaks in the paper of its being preferable, if you have to stop making for any period greater than ordinary meal-time, to draw the whole of the bricks

off, and start, apparently, *de novo* with the next working period. I do not know whether he is working more than one shift per day, but if not, how does he get over the difficulty of clearing away the bricks which are in the dryer at the end of the shift? Does he find it necessary to have an extra gang working a second shift to take off the goods that are in process of drying? I would rather like to know this. The only other point I would like to bring forward is that I cannot see why the designers did not follow the thing out to its logical conclusion, by tacking a tunnel kiln on to the end of the dryer, with a rail conveyor to take the bricks to the other end. They would then have had no more to worry about.

Mr. A. H. Middleton:—I would like to add my thanks to Messrs. Holland and Gardner for giving us such an admirable paper and illustrating it so thoroughly as they have done. Some remarks were made in the paper about this apparatus being regarded as a humidity dryer. I do not see any reason why it should not be. It has the same features as the Proctor dryer—at least it has one of the same features, inasmuch as you take the moisture of your bricks into the dryer, and that is the only method of getting water into a Proctor dryer, viz. :—just the moisture that is carried in along with the bricks. But whether it is actually worked as a humidity dryer would depend upon the way in which you work it. One of the features of the Proctor dryer is that there is no inlet of air at the wet end of the dryer. But although there are the cross currents blowing across the bricks and keeping the air in motion there is not an air outlet, so that the moisture is kept in. You are simply drawing air across. I do not know whether it would have the effect of keeping the atmosphere almost dry or whether you have any humidity or not. Another point that the authors make is the reduction of floor space. If the apparatus is worked perfectly regularly and you always have a kiln waiting to take the dried goods away, of course you would then have a big saving in floor space; but I should think that probably very often you would find it necessary to pile somewhere. I know that we have not always a kiln ready to absorb the dry goods and in that way we do not find that the Proctor dryer or any other system of tunnel drying does actually save floor space. At all events, it does not save us any covered-in space. We have in use as much area of roofed-in floor space with the Proctor system of drying as we should have under the hot floor system, for the simple reason that we have not always a kiln ready, and we have to keep a goodly number of truck loads of stuff under cover waiting for a kiln. Therefore, we do not save any floor space at all, although the actual amount of drying area is undoubtedly reduced.

Mr. J. Holland:—Personally, I should think that the conveyance of the empty plates from the finishing end to the making end could be readily overcome by placing them upon a travelling belt. There should be no difficulty about this at all.

SIR WM. J. JONES:—I have not seen the dryer, but I would like to ask a question. Who attends to the furnace? What I have in mind is that the disadvantage of having to return the plates to the inlet end might be overcome, if the running of the works lent itself to it, by reversing the operation of feeding and withdrawal in the case of twin stoves. It seems to me that it would be a distinct advantage if the apparatus could be worked in that way, as it would save the taking back of the plates from one end of the stove to the other.

MR. A. H. MIDDLETON:—Did I understand Mr. Gardner to say 4 cwts. of coal per day, and that with this consumption he dries 5,000 bricks? That is less than a cwt. of coal per thousand. I should say that is remarkably good.

MR. GARDNER:—Yes.

MR. GARDNER:—Replying to Dr. Cronshaw: I do not see why the plates should not be perforated if it is desired to have them so, although I do not know that there is going to be any particular advantage in this.

With regard to the costs, I am not prepared this morning to go into that question. The stoves, as we have them to-day, were built during the war period, when everything was very costly. We have not taken out the present valuation and I am not in a position this morning to tell you much about this. Probably this particular battery of stoves cost us at that time something like £2,000.

With regard to Dr. Cronshaw's suggestion as to piling the bricks, I presume he means that instead of having one plateful of bricks, two or more rows of bricks might be piled on one plate, that is on the top of one another. I think I should rather object to that because I do not think you would get them dried properly, and again, you would probably get much waste. It is possible that you might economise considerably by having more than one tray, one placed above another. But you would need to have a much larger current of air. It has occurred to us that we might perhaps fill up the space a little more, but to do this we should have to make considerable alterations. The stove is only in its infancy at present. The idea has not by any means been brought to a conclusion, and, therefore, such suggestions as Dr. Cronshaw has made may be very useful for future guidance.

With regard to the possibility of the workmen neglecting their job: it is impossible for them not to fill the stove properly, even if they are engaged on a night shift, with plate following plate, and a piece-work system of pay does not encourage slackness.

With regard to humidity, I am sorry we have no firm data to give at present. I do not think that the atmosphere is completely saturated, even at the forward end. We have never considered this plant to be a competitor of the "Proctor". In fact, the Proctor dryer was not in our minds when we designed it. It may in some respects resemble it, due to the fact that we have

quite a lot of humidity at the front. As to velocity of air: the bricks, after passing through this stove in four to five hours, are quite strong—so strong that you can pile them up and stand on them, without doing them serious damage. And so long as they will stack in the kiln without falling, even on a damp day, you have not much to fear. We stack them 14 high and have never yet had any difficulty or trouble in this respect. It is, therefore, quite apparent that the velocity of the air (about one-tenth of an inch) that we get from a 30 feet high stack is sufficient. The working temperature of the stove is about 100°C. at the centre.

Col. Thomas raised the question of what we should do if the stove were working only one shift. It does work one shift, when we have not sufficient orders to work two. But when we are only working one shift we do not leave the bricks standing over the furnace during the night. That is not advisable. Although the arch and the thickness of the floor of the stove over the furnace is increased for that purpose, we do not find it good practice to leave the bricks standing for any length of time; so we draw down empty plates over the area above the furnace. We do not find any ill effects from the bricks standing in the rest of the tunnel.

Replying to Mr. Middleton, I have already stated that we are not in competition with the Proctor Dryer, and I regret if our mention of the "Proctor" has in any way anticipated the paper that Mr. Middleton is to give us. In some respects our dryer may be a humidity dryer, due to the fact that we have much heated moisture at the front. I think that if we were going to build another dryer, we should arrange for the draw to be somewhat slower. We should also thicken the floor at the inlet end and gradually thin it out at the other. With this improvement, I think the dryer would give more even drying and be remarkably efficient.

With regard to Sir William Jones' remarks about the plates: I do not quite follow him. But I do not see how we could take the plates off and put them on again at the same end. The question of attendance is not a very serious one. It requires only one man two hours a day to attend to the fires; the temperature is not very great. We only use about 2 cwts. of coal per stove per shift, and we can dry about 5,000 bricks with that consumption per day in the two stoves. You must remember that they are only three feet wide. The cleaning of the fires is quite a simple matter. It is done, as a matter of fact, by the kiln fireman, who goes round every two hours and stirs the fires, and at the end of the shift cleans out. At the other end of the stove there is a man always working, taking off the bricks from both the stoves. The attendance implies therefore: one man one day, and a fireman about two hours per day, who is engaged during the rest of the time doing something else. The costs, generally speaking, work out at no more than about two shillings per thousand bricks. With regard to the question

of stacking, it is perfectly true that we sometimes have to stack. If we could always send direct to the kiln that would be a great economy. If we stack we have to pick the bricks up again, and that entails cost, But even if we stack we are saving floor area. The most costly system of drying undoubtedly is the hot floor. We have to use flats for large lumps. Mr. Middleton could dry lumps with his Proctor drier, but we cannot in this particular plant. We could probably take lumps equivalent to about the size of five ordinary square bricks, but with a stove of this type I do not think it would be practicable to deal with lumps very much larger than that. Therefore, it is not an economical lump-drying plant. But for ordinary sized bricks and squares we have certainly found it effective, and it is working up to the present very well indeed. In conclusion, I may say that the stove was really built, in the first place, on account of the men. You will remember that it was put down during the war period, when we had to work at very high pressure. When we saw our workmen stripped to the waist, on a hot July day, turning out as many as 2,000 bricks per day each, and wheeling all their own silicon to the stove, we came to the conclusion that it was high time some move was made, however inadequate it might be, to improve the conditions in this respect. With a system of this sort you can have something like cool conditions in your sheds. With a flat floor system you cannot. And if you make the conditions better for your men by eliminating dust and heat, you are bound to get better work from them in consequence. That, of itself, will prove a great economy.

V.—Collecting Flint Dust.

By A. E. Harris.

THE problem of the removal and collection of flint dust in the pottery industry is one which for many years has been given considerable attention in the joint interests of operatives and employers.

In the early days scrappy attempts were made to deal with this problem by only a few manufacturers, but later, legislation directed the attention of the trade generally to the necessity of preventing flint dust and certain other dusts from escaping into the atmosphere among workpeople. It is now acknowledged in the industry that the efficient removal of these dusts from the inner atmosphere of the factory is a matter of importance, not only for reasons of safeguarding employees from the bad effects of dust inhalation, but also because it is realized that a dusty atmosphere is detrimental to the general efficiency of both the human and mechanical elements of the factory.

From time to time various methods have been introduced with more or less success for removing dust from enclosed atmospheres. The earlier attempts were by mere ventilation of the rooms of the factory by volume fans placed in the walls, but while this method alleviated the trouble to some extent, it was seen that it did not get at the root of the problem, and thereafter means were employed which aimed at arresting the dust at its actual points of formation. To this end the volume fans gave place to enclosed type machines which were directly connected to the points of dust origin by systems of ductwork and this formed the basis of the modern methods of dealing with the problem. In all such installations the proper design of ductwork is an important factor and the general success and economic working of such systems depend largely upon whether sufficient attention has been paid to the design and arrangement of the ducts themselves.

It is regrettable to note that it has sometimes been found by specialists in these plants that the application has failed owing to the ducts and hoods being ill-designed and constructed, thus emphasizing the necessity of giving full consideration to these points before adopting apparently cheap schemes for dust-removal plant.

The best means to be adopted for the efficient removal of the dust will largely depend upon the manner in which the processes are carried on and the lay-out of the workshops. Wherever the operation is carried out by hand, as in towing and fettling, it is usual to remove the dust by means of a hood, which must be so placed as to draw the dust directly away from the operative.

These hoods must, of course, be designed to suit the particular local conditions and in consideration of the arrangement of the general duct system; but in any case, they must be so constructed as to concentrate the draught and to direct efficiently the dust-laden air into the ducts, while also giving perfect liberty to the operative. In cases where dust has to be removed from an enclosed machine, such as in scouring, the branch pipe should be slightly expanded at the connection to the machine-casing, so as to allow of a gradual increase in velocity of the air being drawn into the system. In all cases branch pipes should be led into the main duct in such a way as to give easy flow to the air currents through any changes of direction and should also be fitted with dampers, so that the amount of air passing through them can be kept under constant control. The branch pipes should also connect with the main duct not lower than the centre line of the latter, so that any settlement of dust in the main duct does not also block the orifice of the branch pipe. A good deal of importance attaches to this point, so as to preserve the full efficiency of the branch pipe, and also since these parts of the system cannot generally be constructed for easy cleaning out. The position of the main duct, however, is one of the chief features in deciding the construction of the branches and if, as in trunks from towing benches, this can be placed on the floor below the points where the processes to be exhausted are carried on, a good deal of difficulty is avoided. In such cases the branch pipes can usually be readily attached to the top of the main duct in such a way that no dust can settle in the branches; but where the main duct has to be placed overhead, the prevention of dust settlement in the branch pipes calls for special attention. This could be overcome by giving a higher velocity to the air currents, but as this is not, for various reasons, desirable in these parts of the system, the alternative is to construct the branches in an angular fashion which would not permit any dust deposited within them to accumulate. For ordinary purposes of dust removal it is the common practice to keep the velocity of the air in the branch pipes as low as practicable and in designing these, therefore, it is important to see that they are of sufficient area so as to give as little resistance to the air currents as possible.

The design of the main duct depends upon whether it is required to settle as much dust as possible within it or not. If it is designed to encourage dust settlement, it can be constructed to give a speed of as low as 3—5 feet per second to the air passing through it, and in this case it is not essential that it should be graduated in cross-sectional area at points where differing volumes of air are to pass through it. With such ducts it is, of course, necessary to provide adequate means of access for cleaning-out purposes. The actual cleaning-out process is usually done periodically by hand, but in some cases the bottoms of the main ducts are made hopper-shape and provided with spiral conveyors of small diameter which con-

tinually clear the settlement. If, on the other hand, it is intended to prevent dust settling within the pipe system as a whole, the main duct must then be designed to give sufficient speed to the air currents for this purpose and its cross sectional area must be graduated to maintain a constant speed for the differing volumes it has to accommodate.

The next point for consideration is the fan which is to operate the system, and this unit must not only be calculated to pass the required total volume of air, but must also be capable of setting up sufficient water gauge reading to overcome all resistances of the pipe system. The discharge pipe of the fan should also be arranged with a diffuser piece connected to the outlet tapering at about 7 degrees to a cross-sectional area of not less than that of the fan inlet eye.

Dealing with the actual collection of the dust after removal, it is undesirable for many reasons to allow the dust to be blown directly into outside atmosphere, especially in cases where very little has been allowed to collect within the duct system. It is not uncommon, however, to see factory dust being freely discharged into the open air where it becomes a nuisance to tenants of neighbouring property and also represents a certain amount of loss to the user, since in the case of flint dust it is, of course, the finest of the original product. From time to time various methods have been employed in industry generally for the recovery of dust and the modern equipment for this purpose has developed from the experiences and results of methods put to use during a number of years. In the first place rooms were partitioned off or built in some unoccupied space in the factory and the dust blown into these settling chambers through trunk lines. These rooms were tightly closed with the exception of one or two small openings which were covered with cloth or fitted with baffle boards, thus permitting the air to escape while the dust settled to the floor. At intervals workmen removed the dust which had accumulated on the floors of these rooms. These chambers had many disadvantages, the chief being that they occupied valuable factory space which could have been put to more profitable uses. Besides this, and although they are sometimes used to-day, these chambers have never in any sense completely recovered the dust and are usually regarded by those who use them as a part of the factory to be avoided. Also, in some industries, they were the direct cause of dust explosions and this directed attention to the necessity of developing some more satisfactory system. One of the next experiments of importance consisted of a large box with hoppered sides and a conveyor at the bottom to remove the dust settlement. A series of curtains or baffles within the box deflected the air currents and caused the dust to drop. Another form of collector had a vertical cylindrical chamber with cloth walls arranged in zig-zag fashion to give the maximum of filtering surface. It had a conical hopper which dis-

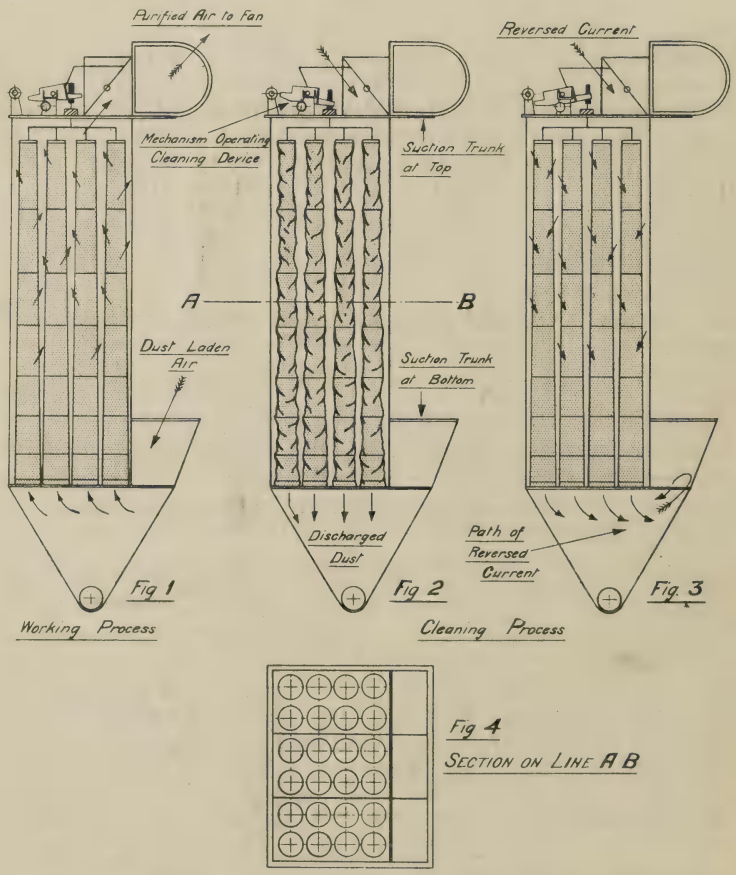
charged the dust through a weighted valve into a conveyor or into sacks. A later step in the development was the introduction of the dust-laden air at the side of the cylinder instead of at the top, which led to the discovery that the conical hopper gave a whirling motion to the air which deposited the dust at the bottom of the hopper. This machine was the forerunner of the modern cyclone collector.

Many improvements have been made iu the cyclone type of collector in recent years. Experiments have shown that the best results can be obtained with certain length of cones, and tests have shown the proportion which should exist between the inlet, outlet and discharge, for the most efficient operation of the collector. Some difference of opinion, however, exists on these questions but makers are working towards a standard type of apparatus for each distinct purpose. It has been proved that cyclone collectors are not, in many cases, efficient in dealing with fine dusts, and where they are used for this purpose, a considerable proportion of the finest of the dust escapes to atmosphere with the discharged air. They are, however, commonly used for collecting coarse and heavy dusts, such as in saw mills and foundries, and are also extensively used for dealing with the dust from wheat-cleaning plants of flour mills.

The next advance made was with tubular filter collectors. The early models of these consisted of an upper and lower chamber with a number of cloth tubes fitted between. The dust-laden air was blown into the tubes through the upper chamber and the air allowed to escape through the tubes to atmosphere. The dust was removed from the tubes by mechanically-operated chains or by occasionally shaking the tubes by means of a hand-operated lever. The dust thus removed was deposited in the lower chambers from which it was removed by hand, or in some cases by a screw conveyor. These machines were by no means entirely satisfactory and occasionally gave some trouble, but they formed the basis for many experiments, which aimed at recovering the dust before the air currents had passed through the fan. This permitted more efficient methods to be adopted for removing the accumulated dust from the sleeves of the machine. Upon these lines the modern suction filter collector has developed and is now extensively in use in many industries.

This machine operates under a constant vacuum and has been proved to be an efficient collector of even the very finest dusts. Moreover, it is entirely automatic in its working. It consists mainly of a wooden or sheet steel casing divided into compartments, each compartment containing a number of filter tubes which are open at their lower ends. The lower ends are fixed to the casing by means of an expanding steel ring sewn into the tube and let into a recess provided in the tube orifices in the base of the tube compartments. The upper ends are closed by iron covers and are suspended

from an adjustable rack in each compartment which, in turn, is suspended from a rod connected to the cleaning mechanism situated on top of the tube chambers. The tubes are made of suitable filter cloth for effecting a complete recovery of the particular dust to be dealt with, and the accumulated dust is removed from the tubes in a simple but efficient manner by mechanical shaking combined with reversed air currents, which periodically and automatically act on the tubes of one compartment at a time.



The working process of the machine is illustrated in the diagram. The machine is connected to a fan from one end of the upper discharge trunk by a suitably arranged duct and the suction thus produced in the casing should always be sufficient to deal adequately with the dust at all points of origin. The dust-laden air is thus drawn through the pipe system into the tubes of the

machine, as shown in Fig. 1., entering the casing diagonally opposite the position of the air discharge to the fan. The dusty air currents enter the tubes through the openings at their lower ends and the air passes through the walls of these in the direction of the arrows. During the working process of each section of the machine, the baffle in the box above the compartment is in the position as shown in Fig. 1 which permits the air passing through the tubes to proceed

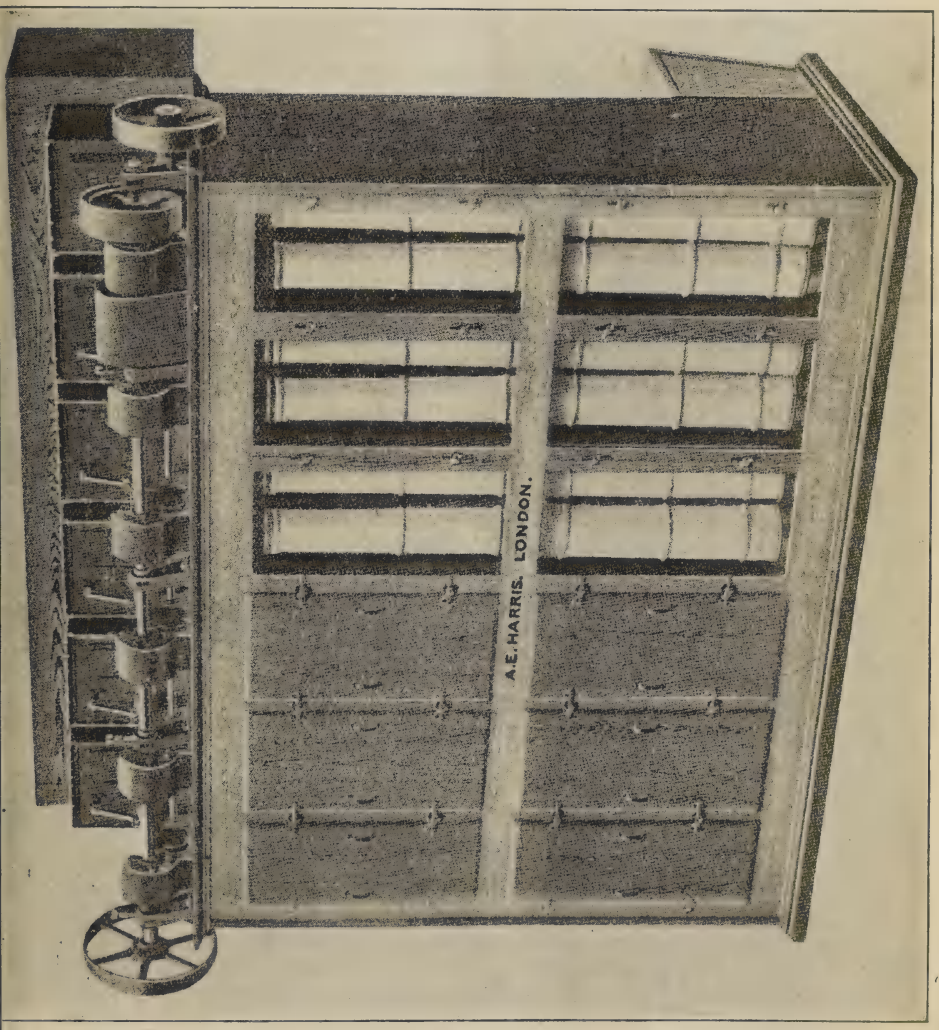


Fig. 5.

direct to the fan to be discharged. Provided the right grade of filter cloth is used, the dust is completely retained on the inner walls of the tubes. At intervals of two to three minutes each compartment of the machine is in turn cut off from the dust-laden currents by the mechanism which reverses the position of the baffle above the chamber, and the particular compartment then comes under the cleaning process as shown in Figs. 2 and 3. The reversing of the baffle allows a current of atmospheric air to be drawn into the compartment through an adjustable port situated in the front of the baffle box; this air passes through the walls of the tubes in an opposite direction to the working currents and in doing so carries with it the dust from the pores of the filter cloth. At the same time the tubes of this particular compartment are repeatedly shaken by the mechanism and by this combined method the dust is thoroughly removed from the tubes. The dust thus removed is deposited in the hopper of the machine while the reversed air currents pass into neighbouring compartments with the ordinary working currents. This cleaning process takes place at regular intervals throughout the whole of the machine, which is thus constantly maintained in an efficient state. The dust deposited in the hopper is discharged through an air-lock valve into sacks, or otherwise as desired. The power required for driving the mechanism is less than 1 h.p. and no attention is required other than occasional lubrication and inspection. The tube compartments of these machines are conveniently arranged with inspection doors, so that the tubes can be readily inspected or changed if necessary.

As an instance of the efficiency of the machine described above, it may be mentioned that they have been installed for recovering metallic oxides from the flue gases of smelting furnaces and also for recovering the solid material from the air currents of spray-drying plants. In such cases, of course, the dust particles are extremely fine, but where the machines are dealing with this product, they are giving a recovery of 98 per cent. of the powder as an average figure. In these cases, also, the machines work in a temperature of approximately 220° F., but this does not in any way affect their general working.

A further distinct advantage with this type of machine is that no dust passes through the fan operating the plant, so that the wear and tear on this unit is reduced to a minimum.

DISCUSSION.

Mr. H. E. Wood:—I hope, gentlemen, that you have assimilated all the information that Mr. Harris has given you. I am afraid I have not, although I have been doing my best, but, I am not an expert engineer. It has been very interesting to be reminded in the course of the lecture of what many of us have been through. The lecture seems to have been a sketch of the evolution

of various types of dust collectors from their infancy. I think that they had, at the works at Burslem with which I am connected, one of the very first plants that was installed in the district for the removal of flint dust. Of course I know that we should be laughed at to-day for ever having had anything of the kind. But we have moved gradually along and I suppose that we shall have to have something even better still. I regret that I was not able to follow the lecture as I would have liked, but there was one point on which I was far from clear. It occasioned me a good deal of surprise to notice that in the newer collecting tubes we are apparently advised to arrange for quite a number of angles. The one great thing that has been impressed upon my mind in the course of 15 or 20 years' experience is that, whatever else I do, I must not put angles in the tubes; or, if I allow angles to be put there, I must round and soften them off, so as not to restrict the pull in any sense whatever. I am afraid I am not competent to judge which is the right procedure to adopt. I merely mention the matter in order that the lecturer may have an opportunity, if he cares to do so, of making this particular point a little clearer.

Mr. A. Fielding:—There is one thing I would like to ask the lecturer. He makes a point of having the ducts sufficiently narrow to prevent any deposit of dust. Now what is the objection to having a duct considerably wider than that necessary to collect the dust? When we do away with friction would it not take less power to suck the air along the duct? Also, a good many of the installations which have been touched upon to-night have been rather more applicable to such processes in pottery decoration as aerographing. The more general question of dust collection in potters' shops, about which I hoped we were going to hear something, has not been touched upon. Now, in connection with aerographing, we do not want to suck any more colour into the atmosphere than is absolutely necessary, and in that event what is the objection to having a wider duct, such as that we already use, connecting with a wooden trough at the back of the plant, as against a narrower duct such as that described, collecting into what I should imagine are rather expensive sorts of chambers, which the poor manufacturing potters at the present time, I should think, would be rather inclined to fight shy of? It is quite true that in the past all our efforts to deal with such problems as this have been the result of rule of thumb. We have had to blunder along and devise something which would do the work. Like the Chairman, I am not an engineer, and I confess I could not follow a good deal that was contained in the lecture. I should imagine, however, that the elaborate plant for dust collection which has been described to us is rather more adapted to an industry that is concerned with one concentrated purpose. As a flint cracker or a stone crusher it might be excellent, but what we want in the pottery industry is something that can be adapted to a whole room, where dust is

floating about in a very fine form. This latter problem does not yet appear to have been tackled and solved efficiently.

MR. HARRIS:—If I follow the speaker rightly, the question is: Why should not ducts be made sufficiently large to prevent pipe friction, or almost eliminate it, and at the same time collect the dust deposit in the trunks?

MR. FIELDING:—Yes, that is what the question amounts to. But I would also like to ask why the suction should not be downwards instead of going up first and then coming down.

MR. HARRIS:—Dealing with the first part of the question, I see no reason at all why ducts should not be used as a dust collector, provided they are originally designed with this point in view. It is sometimes the practice, to make these ducts—particularly the main ducts—as large as possible, so as to encourage settlement in cases where no actual collector is installed in the system. But the objection that most industries have to installing large ducts and using them as collectors is that they constantly need cleaning out, which entails a certain amount of labour cost. In the pottery trade this question of labour charges may not, perhaps, matter very much, but in a great many trades they are not prepared to spare labour and shut down the plant for a half day or a whole day in order that the dusty trunks may be cleaned out. They usually prefer to have a system which does not encourage but rather prevents dust precipitation, thereby obviating, even occasionally, the shutting down of the plant for such purposes. Another serious objection to dust settlement within the ducts is that unless the accumulation is frequently and regularly removed, the air currents passing through the system cannot readily be kept constant and the installation is therefore likely to become insufficient.

Dealing with the second part of the question, as to why the branch pipes should not go in a downward instead of an upward direction, there is no reason why they should not do so (if the position of the main trunk will conveniently permit this) If it is possible to take a branch pipe direct into the main duct without risk of dust settlement, it is not, of course, necessary in such cases to adopt an indirect direction of flow.

MR. E. A. R. WERNER:—It has been very refreshing to me, as a member of the Society who lives at a distance, to have had an opportunity of listening to a most interesting address. I think we shall all be in agreement that Mr. Harris has given us a great deal to think about. What we emphatically need, not only in the pottery industry, but in all industries to-day which are in the stress of competition, is new ideas. You yourself, sir, touched on the somewhat bold way in which the lecturer has shown on the screen to-night illustrations of the very things that we have been condemning for something like twenty years. When I say *we*, I mean, of course, such acknowledged experts as the late Mr. Pendock, and others who have published reports on ventilation, and

with whose work I have been privileged to be associated in various capacities. I think I may venture to claim that there is to-night in this room a very large body of practical experience on the subject of ventilation which has been built up locally during the last 30 years. First of all, I would like to suggest to Mr. Harris that it might be well worth considering whether that attempt to remove dust upwards is worth making. As the result of experience which has been gained by extensive practical experiments, not only in the pottery trade but in other industries in which there are dusty processes, we have been forced to the conclusion that (for dusts which are other than extremely light) the most generally satisfactory method is collecting downwards or backwards or downwards and backwards, and then getting rid of the dust collected. If you take the dust upwards you inevitably cause a tendency for it to circulate unless you are exhausting from a well-enclosed space. I am not attempting to put this forward in any sense as a theoretical counsel of perfection, or as detracting in any way from what may be put before the Society as a theoretical counsel of perfection. But the trouble is that we have to deal with existing fans and engines and motors which are not always working up to a 100 per cent. efficiency; there comes a day when there is an overload on the machinery and the fan is not getting its full supply of power; or it may be a day when the belts are loose and slip and you lose 20 per cent. of your efficiency in that way; or perhaps the motors may not be working well; and as soon as you get down to what Mr. Harris has put before you as the theoretical minimum speed for which the ducts are designed, the dust begins to find its way back again, and you are simply churning it up instead of removing it out of the shop as you are seeking to do.

I was somewhat shocked when the second figure was put on the screen showing tapered inlets going into the main trunk at a dead right angle. That, I should think, must surely be an error on the part of the draughtsman. I think Mr. Harris will agree with me that 30 degrees is the ideal angle to aim at in order to get the currents to flow in the same direction, just as sewage engineers recognise something like that to be the optimum for a branch sewer running into a main.

Among the new ideas that have been brought before us to-night for our consideration, I think the application of low velocities and a screw conveyor an admirable suggestion, and certainly it would take up very little power. In the same way I think we should be immensely indebted to Mr. Harris for putting before us in complete detail that extraordinarily ingenious form of collector with a mechanical cleaning apparatus. Mr. Harris has told us that a collector of that sort will work in practice with an expenditure of about one horse power. Moreover it is a collector which comes in between the source of the dust and the fan. Therefore, it is under a sub-atmospheric pressure. We know that in practice ducts and

containers used for purposes such as this invariably leak after a year or two, if they do not to some extent from the very first. If they leak and they are under a sub-atmospheric pressure, there is no harm done; all that happens is that a little extraneous air is brought in. If, however, you use a filter-chamber on the delivery side of the fan, you are not only exposing the blades of the fan to the wear and tear due to the flint dust, but you are also exposing this potentially leaky chamber to a pressure greater than the atmospheric pressure outside and, therefore, your dust is coming out through any available crack. To go into all the questions of alternative systems of dust collection would provide matter for a whole series of evenings, so I cannot attempt this in the process of proposing a vote of thanks. I should, however, like to say that we have had designers who have thought the problem out very carefully and have produced efficient systems with short and wide ducts, even with a open-bladed propeller fan. It is possible to remove enormous volumes of air at low pressure with a very simple system just as efficiently as by means of an elaborate one. But there again, I think you want to collect on the exhaust side; otherwise you will have to take out your propeller fan and put in a cased fan. A question arises with regard to the horse power which would be required with this collector: not merely the horse power necessary to drive the well-designed collector, but the horse power needed to drive the fan which is to exhaust the air through that collector. You have to start with the horsepower for an average system—possibly a 10 horse power motor; you might have to double that to pull it through the collector. Then, what will be required to take it round those angles? Every right angle diminishes the efficiency of the system by a substantial percentage, and some of the angles shown in the drawings were even sharper than right angles. What total horse power would be needed to ensure, at the collecting end, anything like 1,500 or 1,800 linear feet per minute. I am hoping Mr. Harris will tell us that it has actually been done and with what horse power it has been done. I think the Society will agree with me that some figures are rather necessary on that subject.

I hope that our visitor, whom we are specially pleased to have with us here to-night, and who has given us so much to think about, will not feel that it is detracting from the reality of our appreciation and the heartiness of our vote of thanks if I, as the proposer of the vote of thanks, retain some little mental reservation with regard to the duct work and the hoods and so on. I can, at all events, say that I have spent scores of evenings without gaining such valuable new ideas as I have gained to-night from what Mr. Harris has told us of the mechanical cleaning of ducts and bag filters. I have very great pleasure, therefore, in moving a vote of thanks to Mr. Harris for his very instructive and interesting lecture.

Mr. Harris:—With regard to the point raised upon the method of connecting branch pipes to the main trunk that particular view

on the slide was an end elevation of the pipe and, unfortunately, it did not show the detail that would have been shown on a plan view. If I had been able to show you the pipe from another view point you would have seen that the direction of its flow into the main pipe is approximately 30 degrees. In the fourth illustration, which was a reproduction of an actual photograph, you would see that the branches came into the main at a very gentle angle.

Mr. Abraham Fielding:—I have very great pleasure indeed in seconding this vote of thanks which has been so ably proposed by Mr. Werner, whom we are very pleased to see with us to-night. It is very gratifying to notice the interest which Mr. Werner displays in the proceedings of our Society. I am entirely with Mr. Werner in saying that we have spent a very profitable evening, and if we can get other gentlemen, of similar ability to that of Mr. Harris, to come and instruct us on matters about which we obviously know so very little, we shall no doubt make more progress than we have done up to now. We have learned a good deal to-night. I was particularly interested in that question of filtering. I am not at all certain that it would not pay some of the pottery manufacturers, who are blowing colour away into the atmosphere and incidentally upsetting everybody in the particular neighbourhood of their factories, to consider putting in an apparatus on these lines. With regard to the question of horse power, which Mr. Werner has mentioned, I had intended to bring that matter forward and to ask whether the 1½ h.p. which Mr. Harris mentioned was the amount of power that is simply used to suck the dust through the filters. It cannot possibly be sufficient to draw it through the duct. I am also in agreement with Mr. Werner that we ought to know something more about the horse power that is consumed in overcoming the resistance to the bends. I should certainly consider that it takes far greater horse power to do it in that form than in our simple manner of sucking the dust downwards. The weight of the dust does help the suction to some extent. Then again, it would be interesting for us to have some information in regard to the bends. From the engineering point of their businesses the potters are extremely backward. If for instance, we could get someone to teach us something about boiler smoking chimneys and how to overcome that in a simple and inexpensive way we should be doing ourselves and the district good, as well as satisfying the Authorities. I believe that the Authorities are quite justified in taking the action they are taking in endeavouring to make us, the pottery manufacturers, save money. There is no doubt about it that we have a lot to learn yet on the mechanical side of our business. In the past this department has been sadly neglected. It is really alarming to consider the amount of steam waste that is going on in some of our factories. I am not going to say anything about the fuel losses at kilns and ovens. If the Society could get someone to instruct us on these points, I believe it would

be doing the industry an excellent service. I am glad indeed to have the opportunity of seconding the vote of thanks to Mr. Harris for his most interesting paper.

MR. HARRIS:—I would like to express my appreciation of the way in which you have received what I have had to say to you to-night. I realise that the points which were raised regarding certain details of the construction of the ducts and also in connection with the horsepower required by the plant for their complete operation, require closer discussion than has been possible to-night. I should, therefore, have much pleasure in dealing with these points by correspondence, in more detail if it is desired. In concluding, I would like to mention that if any time, any of you gentlemen, or the Society as a whole, would care to have any further information in regard to dust collecting plants, not only information as to what has been done but what might be done under certain specific conditions, we shall be very pleased indeed to give you whatever information we have at our command as applying to your particular problems.

VI.—The Effect of Salty Coal upon Refractory Materials.

By L. M. Wilson, M.Sc. (Tech.)

INTRODUCTION.

THE above title suggests that a fuel chemist might reasonably be expected to attempt a solution of the problem without laying himself open to the charge of undue interference, especially in view of the fact that it was first attacked by Professor Cobb, himself a fuel chemist (*J. Soc. Chem. Ind.*, **29**, 335, 1910.) It is unnecessary to state exactly why the subject is so important, for the facts are unfortunately only too well known; or even to dwell upon details of what happens in practice, for this has been admirably explained by Professor Cobb and others. The writer's present intention is to endeavour to contribute a little new information towards helping to explain some of the phenomena already observed.

Thompson[1] has recently published a paper outlining the effects of sodium chloride upon silica and he is now, we believe, continuing this work with various clays. As he uses platinum apparatus quite beyond our means and has been working in this direction for some time, there appeared to be no reason for retreading the same ground. It was, therefore, decided to study the effects of ammonium chloride upon refractory materials, as this substance is found in coke oven gas from salty coal.

In the laboratory it is much easier to deal with ammonium chloride than with common salt, because a platinum furnace tube is no longer required. It dissociates more readily, and should be more reactive in some ways. Finally, the acid molecule is the same in each instance, but here the base is weaker; and perhaps when the sodium chloride results are published we may, by comparison, be able to judge how much of the corrosion is due to the basic component of the reagent and how much to the acid. Since commercial refractories are impure, it was decided to start by experimenting on ordinary samples, because the small quantities of impurities contained in them must play an important part in any reactions taking place.

The Need for Chemical Investigation. The removal of salt from coal seems a difficult business, even by chemical methods on a small scale, while such methods on a large scale would be impracticable. Physical methods are more hopeless still. The only alternative would appear to be to leave salty coal alone as far

[1] Trans. **17**, 340, 1918, and *J. Chem. Soc.*, **121**, 1442, 1922.

as coking is concerned, or to endeavour to relieve the stresses on the oven linings by turning our attention to the chemical changes which take place in them.

History and Acknowledgment. The work described was started at Eskmeals last year, with the kind permission of Professor Wheeler and under the advice of Mr. Rees, who has been working on salty coal problems himself for some years. Since October, all the remaining experiments have been conducted in the Refractories Department of Applied Science at Sheffield. The sources of outside information, which have proved most fruitful, have been a paper by Thompson and an assortment of literature published by J. W. Cobb, which the author was kind enough to supply. Thanks are also due to Mr. J. Holland for advice on points of practical importance.

EXPERIMENTAL.

The first experiments were carried out on a high-grade silica brick. The apparatus consisted of an electric furnace two and a half feet long capable of containing a glazed porcelain tube three feet in length and one inch bore, one end of which led into a draught cupboard, while a two-holed rubber bung was pushed into the other end. A thermo-couple was inserted into the tube via the draught cupboard. A stream of ammonium chloride was passed through the tube by heating two flasks containing ammonia solution and hydrochloric acid solution. The vapour thus obtained was introduced through a glass tube leading through the holes in the rubber.

The brick was broken into chips of a size which would just pass into the tube. In the first experiment a piece of the sample was subjected to treatment in the tube for $3\frac{1}{2}$ hours at a temperature of 750°C., care being taken to see that HCl and NH_3 entered the tube in as correct proportions as possible. After shutting off the reagents, the current was left on for a further $3\frac{1}{2}$ hours to remove any uncombined ammonium chloride from the sample; at the end of this period the furnace was allowed to cool. When the sample was examined, it was noticed that its weight had decreased from 16·2045 grs. to 16·1792 grs., that its colour had changed from a yellowish to a greenish-white, and that the iron spots had become a pale greeny-grey. Physically, the brick seemed quite unaltered, and on breaking it the change noted on the surface appeared perfectly uniform throughout. On analysis, it was noted that the iron content had been considerably reduced. This is shown in tabulated form in Table A.

In the second experiment, the only change in procedure was to raise the temperature to 970°C. Upon examination, the sample was found to be even whiter than in the previous instance, the greenness being barely perceptible. Physically it remained

unchanged and it still showed the same wonderful uniformity throughout. The weight of the sample taken was reduced from 28·4154 grs. to 28·3133 grs.

TABLE A.

X = Untreated Sample. Y = Sample from experiment No. 1.
Z = ,, ,, ,, No. 2.

	X.		Y.		Z.	
CaO	2		1·98		1·98	
Fe_2O_3	·52	1·48	·48	1·40	·35	1·30 "Oxides"
TiO_2	·52		·47		·43	
Al_2O_3	*·44		*·44		·52	
Mag.	·10		·10		·10	
Silica	95·92		96·05		96·12	
Alkali	·50		·48*		·50	
	100·00		100·00		100·00	

*These small discrepancies are no doubt due to sampling trouble, since lumps were taken for treatment in the furnace.

From the table it seems fairly evident that the iron and titanium content can be removed proportionately to the increase of temperature, but the proportions of other constituents remain fairly constant. Any alteration which has taken place in the brick seems so uniform in nature, that there can be little doubt but that the brick examined would behave very well under the influence of salty coal in a coke oven.

Fireclay Bricks. Having made a trial study of a brick of high silica content, it was decided to leave this branch of the subject for the time being, and to make a detailed investigation of fireclay bricks. Chips from a good sample of this type were treated in exactly the same way as the high silica samples. The first experiment was carried out at a temperature of 850°C. Upon removal from the furnace, the sample had been reduced in weight from 8·5800 grs. to 8·3076 grs. The brick seemed of a slightly lighter shade, but on breaking the sample the colour change appeared uniform throughout. The second experiment was another repetition of the former procedure and a temperature of 1,180°C. was maintained. On examining the sample the weight had fallen from 15·0750 grs. to 14·8190 grs. and it had been perfectly bleached all over except for one small corner, farthest away from the gas inlet.

The structure of the brick appeared unaltered. On breaking the sample, it was evident that the bleaching action had not been uniform, a well defined white shell ⅛-in. thick having been formed all round a nucleus which was darker than in the original. When a small portion was strongly heated for four hours in a platinum crucible with a lid, the white areas were seen to increase and the apricot centre to change to maroon, while the crucible was very blackened inside.

TABLE B.

Analysis of original Fire Bricks and of the Sample from Experiment 2

		Original.		After expt. 2.
CaO	..	—		—
Silica	..	66·08		66·39
Al_2O_3	..	24·516	29·4 total oxides	25·26
Fe_2O_3	..	2·82		2·04
TiO_2	..	2·054		2·1
Mag.	..	2·4		2·8
Alkali	..	1·65		1·53
H_2O	..	·19		—
		99·72		100·12

All that this table shows is a reduction in the iron content, otherwise it is likely to give a wrong impression due to various discrepancies, which are undoubtedly due to the difficulty of getting a really representative sample when small lumps are employed for experiments. The possibility of error with this type of brick is greater than with a silica brick owing to its far less uniform structure. The accuracy of this last statement is well borne out by the apparent inaccuracy of the figures.

From work done up to this point we have discovered some useful facts, the most important being that the sample of fireclay used was not affected by the reagent uniformly throughout, but first on the outside, leaving an outer bleached shell; while high silica brick was affected quite uniformly. Another point was the removal of iron in quite appreciable quantities. It was thought that the iron might have concentrated in the dark cores of the fireclay brick samples. Accordingly one of these was examined.

A piece of untreated brick was heated for 6 hours at 1,200°C., and on comparison with a core from the sample treated at 1,200°C. was seen to be of a dun colour throughout as compared with the apricot of the treated core. The iron content of the core was then found to be 1·84 per cent. as compared with 2·75 per cent. in the untreated sample. This shows clearly, that though the core was darker than the original sample, the iron content had not been concentrated in the centre of the treated sample by the action of the ammonium chloride.

It was now decided to see whether a piece of brick could be bleached uniformly throughout by prolonging the length of the experiment, a twenty-four hours run being considered enough to start with. In order to obtain a sufficient and satisfactory supply of ammonium chloride for such a long experiment, the old system was replaced by one in which the solid salt was placed directly into the cooler end of the furnace tube. In addition it was considered desirable to be able to collect any substance removed and to analyse the same, which would be less laborious and more reliable than an analysis of the fireclay after each experiment.

With these facts in mind, the apparatus was reconstructed. The original porcelain tube was replaced by one of fused silica four feet in length, one end of which was blocked by a solid rubber bung while the other end was connected to a small condenser. A large glass suction bottle was fixed at the other extremity of the condenser tube, and to this a second, similar bottle was connected. The latter was half filled with a solution of ammonium carbonate in ·880 ammonia, through which the gases for the furnace could be drawn. This second bottle was connected via a third to a water pump. These additional complications were found necessary in order to stop all the products escaping from the furnace. A large proportion of the removed $AlCl_3$ and $FeCl_3$ now settled in the cold end of the tube, the condenser or in the first bottle. Any remaining over was fixed along with free hydrochloric acid in the second bottle. This apparatus could be easily washed out after each experiment and the iron-alumina content of the washings determined. The washings were always found to be distinctly acid, owing to the fact that ammonium chloride dissociates at high temperature, and that the ammonia decomposes in turn, especially under the influence of reduced pressure.

Manipulation. Though the old method of inserting lumps of material into the tube had many good features, inasmuch as any changes in strength and uniformity could be studied, it was found better to use powdered samples. This overcame the sampling trouble already mentioned and gave better contact. It was thus possible to weigh the powder, which was now contained in a boat with less fear of loss in weight than previously, where bits were apt to chip off and remain in the furnace. When the temperature of the furnace had been raised to the correct degree, the sample was introduced so as nearly to touch the thermo-couple. Pure ammonium chloride contained in a silica boat was then placed sufficiently far up the tube to get a slow rate of vaporisation, and the bung put in position. The water pump was now turned on, so as to assist the reagent to vapourise and keep it moving slowly over the refractory.

The ammonium-chloride was replenished occasionally, and the temperature kept up for 24 hours. After cooling, the refractory was removed and heated in a muffle for two hours at 800°C. This removed any occluded vapours, etc., and reoxidised any portions which might have suffered reduction from the hydrogen of the decomposed ammonia. The sample was weighed and the loss noted, while the tube was washed out and the iron and alumina content of the washings estimated.

A First Experiment with the New Apparatus. It was found impossible to bleach completely a piece of the same firebrick until a temperature of 1,100°C. had been maintained for 24 hours, after which it appeared weaker and broke in a chalky manner. Its weight had been reduced from 6·020 grs. to 5·880 grs; even

after heating in an oxidising atmosphere it seemed to be unchanged, no sign of the maroon appearance returning as was noticed previously. The precipitate from the tube washings was found to contain ·0344 grs. Fe_2O_3 and ·0416 grs. Al_2O_3. On crushing up this treated sample and boiling it in water, nothing was removed, but the remaining iron could be removed almost completely by boiling in dilute HCl ; while another untreated sample lost only the merest traces by either Fe_2O_3 or Al_2O_3 under similar treatment.

The next experiment was done on a powdered sample, the residue from the last experiment, contained in a silica boat. The temperature was 1,100°C. and both the boat and sample were ignited before weighing, and weighed again after the experiment. Details are shown in Table C.

TABLE C.

Before.		After.
Wt. of Boat ..	14·0240 grs.	14·0165 grs.
,, ,, ,, and clay	24·8084	24·5800
Wt. of clay.. ..	10·7844	10·5635
∴ Loss in wt. of boat ..		·0075 grs.
∴ ,, ,, ,, clay ..		·2209 grs.

N.B.—The loss in wt. of the silica boat seemed quite remarkable ; it had a dulled appearance on the inside. On repeating the experiment, the boat lost weight again. It was thought that this might be due to some interaction between it and the alumina or ammonia. This was investigated later and the conclusion arrived at is set out toward the end of this paper.

The treated clay was boiled up with dilute hydrochloric acid for 1½ hours and filtered. The filtrate gave a white flocculant precipitate of alumina on adding NH_3. The residue and filter paper were ignited and weighed. The results can be seen in Table D.

TABLE D.

Wt. of Crucible	16·7449 grs.
,, ,, ,, + Ignited residue ..	27·2541 grs.
∴ Wt. of residue	10·5092 grs.
Wt. of clay before treatment	10·5635 grs.
∴ Loss in wt. due to treatment ..	·0543 grs.

N.B.—This loss of ·0543 grs. was equivalent to the weight of the white flocculant alumina precipitate, which serves to verify that this method of attack does loosen alumina in fire clay.

The tube washings were not examined, but it was quite evident that practically the whole of the iron had been removed and the attempt to completely bleach a sample had proved successful.

The Estimation of Alumina by Direct Methods. Certain washings from the tube happened to be at hand, and it was decided to make practical use of the same. Accordingly they were treated by the phenylhydrazine method for the precipitation of Al_2O_3 alone. The results were successful and it was determined to use this method as a check on future results. The sample appeared

to contain only Fe_2O_3 and Al_2O_3 with just the faintest suspicion of TiO_2. In two instances the Al_2O_3 obtained by this method came out as ·0248 grs. and ·0041 grs. as against ·0253 grs. and ·0045 grs. by difference when the iron was estimated colorimetrically.

A series of experiments was carried out to compare the effects of ammonium chloride at various temperatures. By this time it was considered that sufficient preliminary data had been obtained and the apparatus so perfected, that it was possible to do a series of experiments under exactly similar conditions, beyond a slight reduction in temperature on each occasion. Twenty-five gram samples were treated in a platinum boat at temperatures varying from 1,265—880°C. for a period of twenty four hours. The samples used had been ground to a 40-mesh and well mixed to ensure uniformity. The methods of working were exactly the same as those described previously, and the samples were collected and estimated with the greatest care. They were analysed primarily to discover the relative proportion of Al_2O_3 in each. The results obtained are shown in tabulated form below.

TABLE E.

	Temperature	Percentage Al_2O_3	Appearance of change after experiment
a.	1265°C.	71·00	Strongly caked, very pale yellow, and stuck to boat
b.	1135	53·60	Slightly caked, biscuit colour.
c.	975	42·50	Less caked, yellow grey, very pale.
d.	915	40·00	Less caked, a deeper shade of grey.
e.	910	13·18	Less caked, a blue grey, very pale.
f.	880	11·00	Not caked, a lighter blue grey.
g.	830	8·00	Not caked, similar to the original.

These results are plotted graphically in Fig. 1.

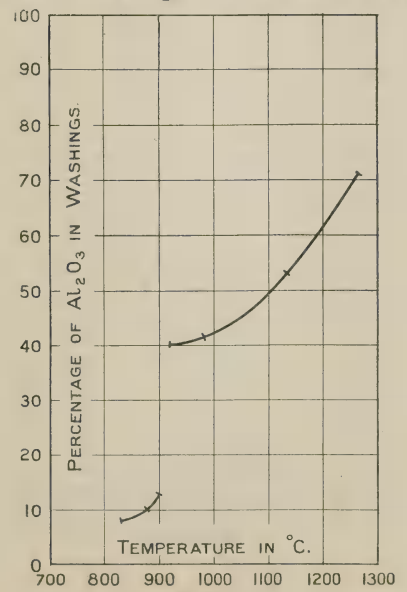


Fig. 1.

From the table we see that by increasing the temperatures we increased the proportion of alumina removed from the brick, while the curve shows that there is a critical temperature of 900—910°C. below which very little Al_2O_3 is removed and above which a great deal is removed. From the foregoing it is possible to conclude that a firebrick, such as the one examined, will be less unsatisfactory below 900°C. when being used in conjunction with salty coal, than at higher temperatures.

Remarks on the Methods Employed. After each experiment, the platinum boat was seen to be coated with a substance both inside and out. This was difficult to remove, but on analysis, it was seen to have exactly the same composition as the rest of the matter extracted from the brick.

But it was decided to conduct another similar set of experiments using a silica boat instead, in view of the fact that this could be cleaned easily after each experiment by boiling in aqua regia, and because platinum might have some catalytic action effecting the dissociation of ammonium chloride, or the removal of Al_2O_3 in comparison with the removal of Fe_2O_3. Furthermore, these results would form a useful check on those previously obtained. Accordingly an exactly similar set of experiments was carried out using a silica boat. The results are shown in Fig. 2. From this it is evident that there is still a critical temperature at approx. 900°C., and that the curve on the right of the break is not a continuation of the curve on the left.

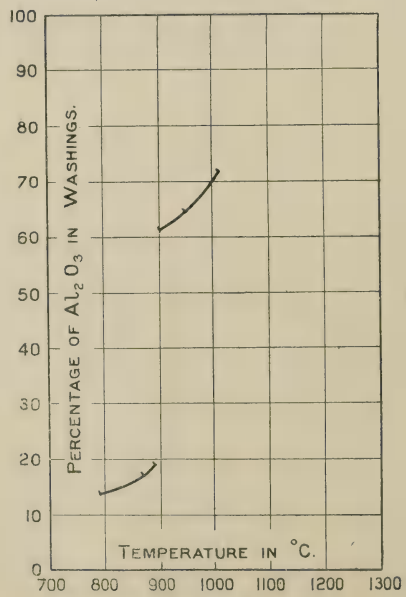


Fig. 2.

Comparison of the curves in Figures 1 and 2 shows that every sample obtained from the silica boat experiments has a higher alumina content than the one obtained at a corresponding temperature with a platinum boat. As already remarked, silica boats, which have been heated in the presence of alumina, and to a less extent ammonium chloride in direct contact, lose weight and become rough and scaley in appearance. There seems little doubt that there has been chemical reaction going on between the alumina and silica, though both have been heated at temperatures well below the softening point of either. As the alumina appears to have reacted in some way with the silica, it seems reasonable to suppose that the silica boat has been responsible for the more rapid removal of the alumina.

In order to discover whether a silica-alumina conglomerate actually survives, a badly corroded silica boat was selected and all the scaley material scraped from its interior and washed with HCl to remove any iron or alumina which might be merely adherent. The scrapings on analysis were seen to possess an Al_2O_3/SiO_2 ratio of 1/83, which seemed to indicate that interaction with the clay had occurred. However, apart from the probable mechanism of things, there seems little doubt that free silica helps the removal of Al_2O_3 from fireclay, exposed to the influence of ammonium chloride at high temperatures.

SILICA REFRACTORIES.

EXPERIMENTAL.

The Comparative Effect of Ammonium Chloride. Having dealt with fire bricks as fully as the time allowed, it was now decided to subject a silica refractory to a set of experiments similar to those just described, with a view to determining its superiority or inferiority as against fireclay with regard to salty coal. Accordingly, a piece of the same high silica brick as the one chosen for the first experiment was selected. This was ground to a 40-mesh and 25 gram samples were treated at 850°C., 900°C., 960°C., 1,010°C., 1070°C., and 1,200°C. On analysis of the substance removed by the ammonium chloride, the merest trace of Calcium was seen to be present in each case, while the Al_2O_3/Fe_2O_3 ratio remained steady at about 10 per cent. in each instance. There appeared to be no sign of any critical temperature throughout the range. From the foregoing it seems just to suppose that high silica refractories, such as the one examined, should be quite satisfactory when used in conjunction with salty coals.

CONCLUSION.

In conclusion it is suggested that:—

1. The observations made regarding the behaviour of silica boats is further confirmation of what Professor Cobb

has already noted, namely, the interaction of solids at temperatures below the fusing point of either.

2. There is a critical temperature at 900°C. where the chemical properties of burned fireclay seem to undergo a change, quite apart from the critical temperatures where the physical properties of either raw or fired materials are known to alter.
3. The experimental evidence demonstrates the superiority of high-grade silica over fireclay for the lining of coke ovens as regards resistance to salty coal.
4. At temperatures between 700—1,200°C. ammonium chloride removes iron and alumina from fireclay; or iron, alumina and calcium from silica bricks.

DISCUSSION.

Mr. J. Holland :—I am sure that you will all join with me in congratulating Mr. Wilson, especially when I tell you that it is his maiden effort. The paper reflects a good deal of hard work, and Mr. Wilson deserves every encouragement. The Ceramic Society gives place to no society, I think, in the encouragement that it gives to the younger workers. We are always glad to see them come forward, and I hope that this sort of feeling will always remain a feature of our Society.

Dr. A. Scott :—Mr. Wilson is certainly to be congratulated on having made a welcome addition to our knowledge of the problem of the effect of salty coal on refractory materials. A certain amount of work has been done in the past in regard to the action of sodium chloride, but very little has been done in regard to the action of ammonium chloride. The reactions which go on between ammonium chloride and the silicates have already been investigated to some extent. For instance, some years ago Clarke and Steiger, in America, treated a number of silicates with ammonium chloride, and they obtained what, at the time, appeared to be rather remarkable results. They found that, in many cases, part of the ammonia seemed to get fixed in the form of an insoluble ammonium aluminium silicate analagous to the similar sodium salts. Where they started with sodium aluminium silicate they found that, by increasing the pressure, they were finally able to complete the replacement of the sodium by aluminium.

A question arises, with regard to Mr. Wilson's work, as to whether part of the ammonia, which is put into the tube, has not got fixed into some form of ammonium silicate, or ammonium aluminium silicate. Has Mr. Wilson made any attempt to determine whether any ammonia has got fixed in such a form ? It is possible that this might tend to break up again by reheating the samples.

There is one other point, and that is the question of the pressure of ammonium chloride vapour in the tube. It is just possible that

some of the variable results may be due to differences in the partial pressure of the ammonia and the chlorine, or the hydrochloric acid in the tube. Has any precaution been taken to get the same pressure throughout all the experiments?

I was rather interested in the remark about the use of phenylhydrazine for the determination of the alumina. I am very glad that Mr. Wilson was able to use that method satisfactorily. It always seemed to me to be a rather messy process, but it is useful to know that Mr. Wilson has used it successfully, because a direct method of determining alumina is often wanted.

With regard to the reaction between silica and alumina, the reaction between solids at much below the temperature of the melting point of either, or of the product formed, is commonly encountered in the refractories industries. In the ordinary case of the silica brick there is a reaction between the lime and the silica at far below the melting point of either oxide or of calcium silicate. It also occurs in connection with magnesite bricks, as well as in fireclay itself.

With regard to the relative merits of silica and firebricks, I do not propose to enter into a discussion. In conclusion, I would simply like to endorse what the President has said in regard to this paper, and to express the hope that Mr. Wilson may be encouraged to continue his work.

Mr. A. H. Middleton:—I most heartily endorse what the other speakers have said in regard to this maiden effort, but I would like to suggest to Mr. Wilson that he has made a rather unfair comparison. I do not recognise the analysis of the fireclay brick upon which he has experimented, but the result of his comparison between silica and firebrick material was rather a foregone conclusion, I should say, from the type of firebrick which he employed. For use in coke ovens, where salty coal has to be employed, no one, I suggest, would make use of a firebrick of the analysis which Mr. Wilson has given. It would have been of even greater value, if the comparisons had been made with a better type of fireclay coke-oven material, and whilst I do not say that the results might not have been the same, I do suggest that the final information would then have been more useful from a comparative and practical point of view.

Mr. H. S. Houldsworth:—I have been very much interested in the work which Mr. Wilson has described and the conclusions which he has reached, and particularly with regard to his second conclusion, where he states that he has found a critical temperature at 900°C., where the fireclay behaves differently with respect to the ammonium chloride. He states that it is not a temperature at which the physical properties of either the raw or fired materials are known to answer. It is an interesting point, which fits in with the work which Prof. Cobb and I described a year ago before this Society. We found that, in connection with shrinkages, there

was a critical temperature at 880°C., where a pronounced shrinkage of the clay takes place, and this has been confirmed by other physical means, such as changes of density and the refractive index of the crystals. It is agreeable to fine that Mr. Wilson has discovered the same phenomenon by another method, and that he is able to confirm that there is a pronounced change in the character of the clay at this point.

DR. SCOTT—I would like to ask whether Mr. Houldsworth gets that critical point when the clay has been fired or in the raw state?

MR. HOULDSWORTH:—I have not held any clay there for any length of time, and therefore, I should not like to say.

VII.—Notes on the Proctor Dryer

By

A. H. Middleton.

LET me say at once that the title I have chosen for this paper should be taken as being a literally correct description of its contents. When Dr. Mellor first asked me to write a paper in connection with the Proctor Dryer, he suggested as a title "The Drying of Refractories." On considering the subject, I soon found that this opened out a field far too wide for me to do justice to in the time that I could at present devote to getting up the subject. I should have liked to have gone into the theory of the subject much further than I have been able to, and to have got out a good deal of comparative data as to the relative time taken, space occupied, and heat used in the Proctor and other systems. But, as Dr. Mellor thought that a few notes on the subject of the Proctor Dryer, by a user, might be of interest to some members of the Ceramic Society, I am pleased to contribute these incomplete notes on the subject.

The Proctor Dryer is used for drying all sorts of materials such as soap, tobacco, and leather, as well as refractory materials. It is essentially a closed, heated chamber, the atmosphere of which is dry at one end and of high humidity at the other. Fresh atmospheric air is drawn in and the dried goods are taken out at one end. Wet goods are put in at the other end and the moisture laden air from the goods is drawn off some distance from this end. The wet goods are, by this arrangement, thoroughly heated to their core in an atmosphere of high humidity before any surface drying can take place. This is the fundamental difference in principle between drying in the Proctor Dryer and drying on an ordinary hot floor.

Description of Machine. The type of machine we have installed at Consett is a three-track tunnel-truck dryer and consists of a rectangular chamber 50 ft. long by 20 ft. wide by 6½ ft. high. It holds 24 cars, 8 on each track, each car carrying 104 pallets with 6 bricks on each pallet, making a total per car of 624 bricks, the total capacity of the dryer being therefore 14,976 bricks. The framework consists of very light angle iron covered with panels formed of thin iron sheets interleaved with insulating material. At the feed end there is a flexible metallic curtain (see Fig. 1), and at the delivery end sliding doors. Each track is fitted with a creeper at the feed end, as can be seen on the photograph, the creeper chain being one car length only, so that, as a car of wet goods is fed into the machine at one end, the whole row of 8 cars is moved forward one car length, thus discharging a car of dried goods at the delivery end (see Fig. 2). Along each side of the chamber

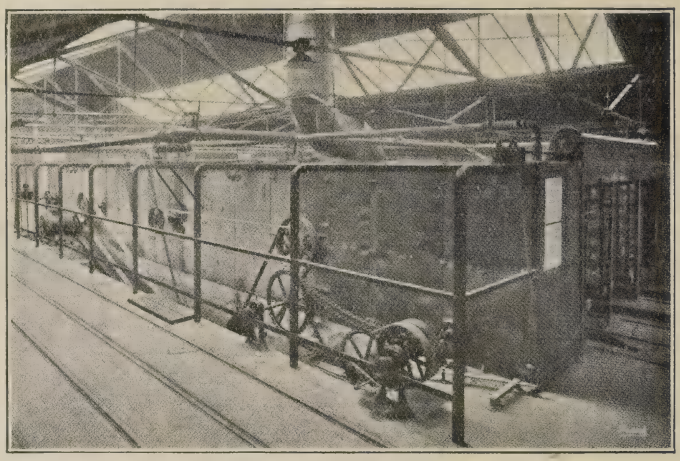


Fig. 1.

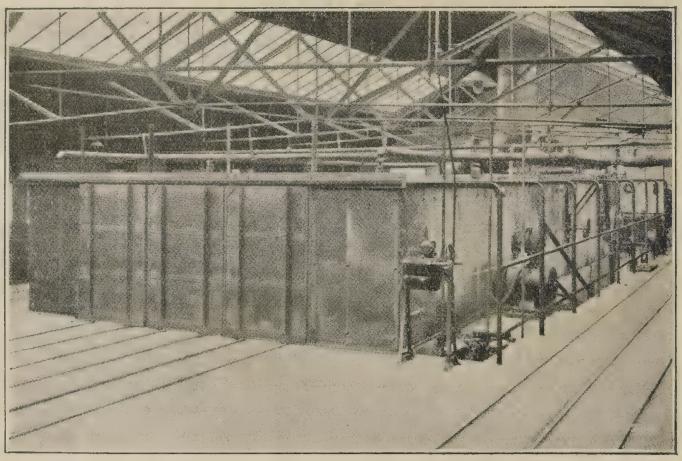


Fig. 2.

a system of fans and steam coils is arranged. The disposition of these will be best understood by reference to Fig. 3. There are four coils on either side the machine each consisting of 616 ft. of $1\frac{1}{4}''$ wrought iron tubing, giving a total heating surface for the machine of 4928 ft. A fan 72″ diam. running at 237 r.p.m. is fixed in front of each coil. It will be noticed that the fans are "staggered," *i.e.*, not opposite to each other. The moisture laden air is drawn off from

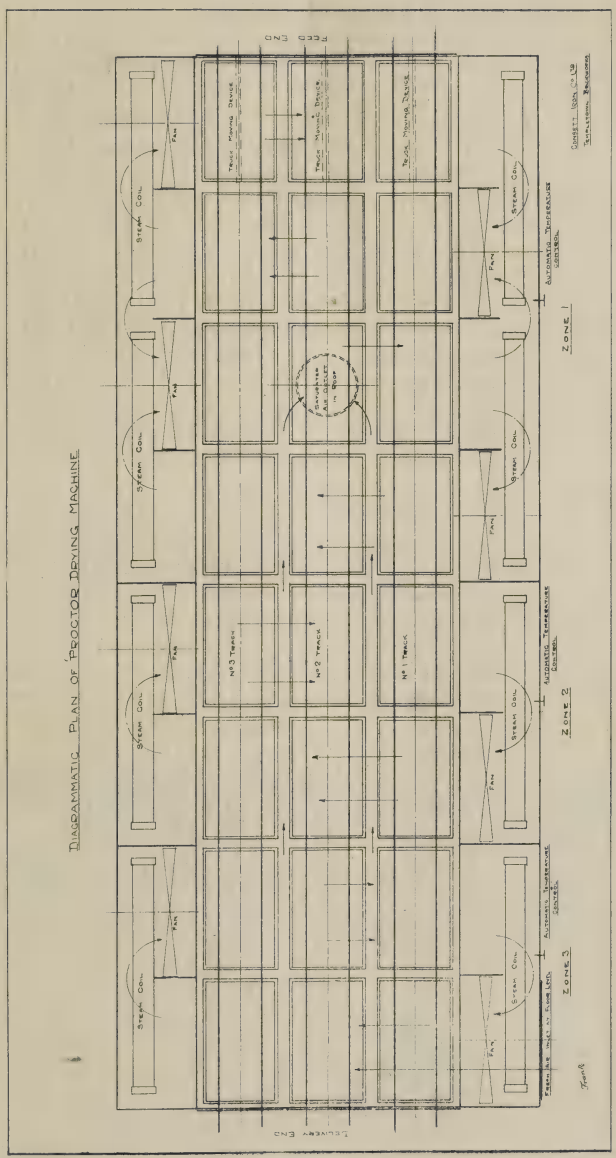

DIAGRAMMATIC PLAN OF PROCTOR DRYING MACHINE
FEED END
DELIVERY END
STEAM COIL
FAN
TRUCK MOVING DEVICE
No 3 TRACK
No 2 TRACK
No 1 TRACK
SATURATED AIR OUTLET IN ROOF
AUTOMATIC TEMPERATURE CONTROL
ZONE 1
ZONE 2
ZONE 3

Fig. 3.

the machine by a fan 32″ diam. running at 685 r.p.m. in a tube which delivers the exhaust outside the building.

The machine is driven by a 25 h.p. motor. The whole of the moving parts are driven from a main countershaft, which is fixed in a tunnel underneath the machine. The temperature control unit consists of a small air compressor and three regulating instruments, one for each zone. Each instrument can be set at any desired temperature over a range 80/220°F., this temperature being maintained automatically. The air compressor sustains a pressure through a control valve on the instrument to a diaphragm valve fitted in the steam feed main, the amount of steam allowed to pass being dependent on the air pressure on the diaphragm. The valve regulation of this pressure is dependent on the expansion or contraction of a glass-filled bulb, which is placed inside the drying chamber. When the temperature inside the chamber is below the determined working temperature, the gas-filled bulb contracts and opens the air valve, which in turn opens the steam valve feeding that zone. As the temperature gradually rises, the air pressure is gradually diminished, and the steam valve very slowly closes until the chamber temperature coincides with that to which the instrument is set, when steam is entirely shut off, and remains so until the temperature falls below that for which the regulator is set. This arrangement has worked faultlessly, and it should be remarked that no damage to the goods can occur through failure of this apparatus, as steam is automatically shut off in case of failure of the compressor or component parts.

Working of the Machine. The machine is divided longitudinally into three zones, not sharply defined by the actual use of walls or curtains across the machine, but by reason of the relative positions of the dry air inlet, the wet air outlet, and the disposition of the fans, baffle plates, and heating coils. Throughout the whole length of the machine, *i.e.*, in each of the three zones, a strong current of air is blown continuously about the goods.

In zone 1, which is practically a third of the machine, the goods remain long enough to get heated right through and lose the greater part of their moisture. We usually maintain this zone at a temperature of 130°F. As no air is admitted at this end of the machine, except when the curtain is raised to admit fresh supplies of wet goods, there is very little displacement of air (*i.e.*, no through current of air), with the result that moisture, given off by the drying goods, keeps the atmosphere in this zone nearly saturated with water vapour. The outside surfaces of the goods are, therefore, prevented from drying at a much greater rate than the inside. The goods arriving in zone 2 have lost, as stated above, the bulk of their moisture. They are now in a condition to stand drying at a higher temperature without fear of setting up cracks or drying strains. In zones 2 and 3 they are, therefore, subjected to progressively higher temperatures and drier atmospheres. The

temperature of zone 2 is 130°/160°F. and zone 3 200°/210°F.

In zone 3 the final drying takes place. The moisture content of the brick surface has been reduced practically to zero, and, as fast as the moisture in the interior diffuses to the surface, it is evaporated and swept away by currents of very hot air of nearly zero humidity.

Time in Dryer. Hours.	Inside of Brick % Moisture.	Outside of Brick % Moisture.
2	11·60	10·58
4	5·70	2·86
5	2·90	1·26
6	1·78	0·70
8	1·00	0·20
12	0·12	0·09
16	0·10	0·06
18	0·08	trace
20	0·04	trace
24	trace	trace

It will be noticed that the goods are nearly dry at the end of 8 hours. If the machine was running on bricks alone the drying could be completed in 12 hours.

We have at Consett, during the last year or so, most successfully dried in the Proctor machines 1½ million of ordinary bricks and nearly 4,000 tons of difficult coke oven shapes and gas retort segments, varying in weight from 2 lbs. to 230 lbs. each.

A reference to the photographs herewith will give a much better idea of their complexity and variety than a verbal description. Fig. 4 shows lumps, varying in weight from 13 lbs. to

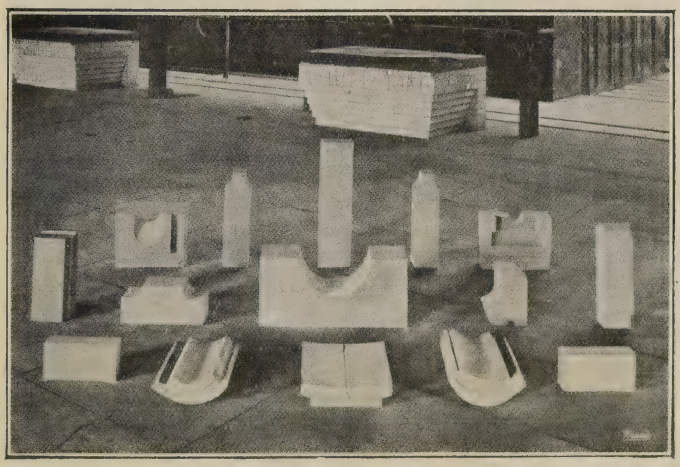


Fig. 4.

160 lbs. each, which were all dried in the Proctor Dryer, at the same time, on tracks worked to different schedules as referred to later. It is mainly because of this variety, and the short time we have had in which to make them, that I am unable to put before you any proved figures as to minimum drying times and steam consumptions, as it is only when running a machine on one class of goods at a time that such data is obtainable. It may, however, be of more practical interest to members to know that such largely varying sizes and shapes can be successfully dealt with in the Proctor Dryer at the same time, than to know the exact time and steam consumptions required for particular classes of goods.

Whilst it is fairly obvious that the best results as to time and steam consumption will be obtained when the machine is used for one class of goods at a time, I should like to point out that the machine is capable of great flexibility in operation and that good and economical results can be obtained by classifying the goods according to the time required to dry them, and working the various tracks in the machine on different schedules. We have sometimes, for instance, in a machine, at the same time :—

A 24 hour track taking small shapes and standard bricks as shown in Fig. 5.

A 36 hour track for medium size shapes as shown in Figs. 6 and 7.

A 100 hour track taking lumps up to 230 lbs. each as shown in Fig. 8.

Fig. 5.

whereas, if nothing but 3″ bricks were being dried, all three tracks might be operated on a 12-hour schedule.

Fig. 6.

Fig. 7.

Some Advantages of the Proctor Dryer compared with the Hot Floor. The drying, especially of difficult shapes, can be carried out much more quickly and with less risk of cracking and setting up drying strains. This is due to the fact that in the dryer, heat is applied evenly to all surfaces, and to the fact that the preliminary drying, as already explained, takes place in a humid and rapidly moving atmosphere, whereas, on the hot floor, the goods are dried in a dry and stationary atmosphere, and if the drying is carried out too quickly, the outside of the goods dries, and therefore

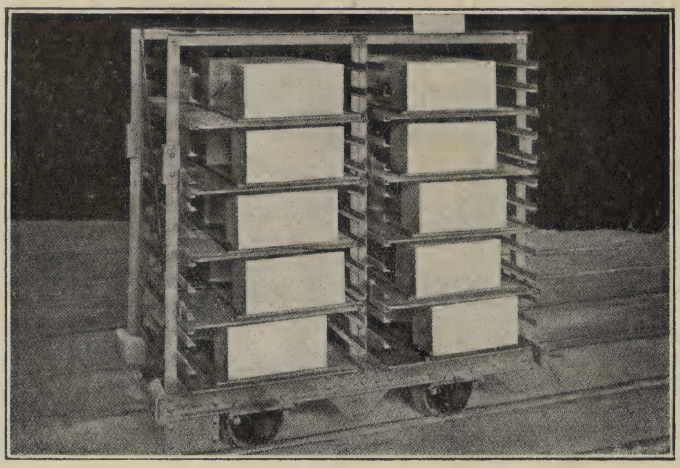


Fig. 8.

contracts, while the inside is still wet and uncontracted.

This appears to be well illustrated in the drying of the big coke oven lumps shown in Fig. 6. These pieces weigh 227 lbs. each. We recently dried 74 of them; 34 were dried in the machine, out of which 3 were broken, and 40 on the hot floor, out of which 16 were broken. The time occupied in drying in the machine was 100 hours—on the hot floor 240 hours. The heating on the hot floor is not uniform, as the surface in contact with the floor is subject to a much greater heat than the other sides. Temperatures I had taken the other day on one of our hot floors showed that the temperature on the floor was 154°F., whereas, at a height of 4½″ above the floor, it was only 86°F.

Healthier Conditions for Workpeople. Where a dryer is installed in place of a hot floor, the conditions in the moulding shop can be made much more healthy and more pleasant for the workpeople. I attach a great deal of importance to this, especially in the silica industry.

Fuel Saving. Except in cases where the heat necessary for drying can be provided from exhaust steam or some source that could not otherwise be utilised, the Proctor Dryer will enable large savings to be made in the fuel bill.

DISCUSSION.

MR. W. J. GARDNER:—The paper has been exceedingly interesting to many of us who have been looking forward for some time to seeing views illustrating the Proctor Dryer, of which we have

heard so much. There is no doubt that it is an established machine for the drying of silica goods in large bulk, and I think it is recognised in America to be a first-class machine for the purpose. I wanted to ask Mr. Middleton if he would tell us something in regard to the costs, because it has been suggested to me that the cost of installing a Proctor dryer is very considerable. I would also like to ask him what is the length of the machine as it has been installed at Consett.

MR. MIDDLETON:—It is 50 ft. long, 20 ft. wide and 6½ ft. high.

MR. GARDNER:—I am much obliged to Mr. Middleton for that information. Will he also be good enough to tell me whether they take out the cars of bricks as they are put in at the other end?

MR. MIDDLETON:—Every two hours we put a truck in. We open the door, set the creeper arrangement which takes hold of the bottom of the truck and this pushes it up one truck's length. This means moving all the other goods one truck's length, and this, in turn, means pushing the last truck out of the machine. The truck moving device is only in contact with one truck at the entry end of the machine.

MR. GARDNER:—Do the brick-makers make their bricks straight on to the pallet, as we see them in the illustration, or are the bricks transferred to the pallet?

MR. MIDDLETON:—They are moulded straight on to the pallet. The pallet is put on the bench and the mould containing the shape is laid face downward on the pallet. The loose sides are stripped off the mould whilst it is on the pallet. The goods are then carried on these heavy, reinforced pallets and put straight on to the rack cars. That is one of the good points of the Proctor system; whilst the shape is in a delicate and moist state, it is never touched at all by hand. The mould is stripped on the pallet and it is put on the car and left standing for a little time until it gets its formation. As a rule, we leave the bricks standing outside the machine for a little while. On coming out of the machine they are bone dry, hard and strong. The principle appeals to us quite as much as the dryer itself. What we like about it is the necessary adjunct of having a car and pallet dryer.

MR. GARDNER:—Would Mr. Middleton care to tell us something about the attendant costs of working?,

MR. MIDDLETON:—In the day shift when we are moulding, there are two men to look after putting the stuff into the dryer, and they have to run all the empty cars back to the moulders after they have been taken out of the kiln, as well as keeping the place clean. During the night shift, when there is no moving going on, we charge every three hours and the boiler attendant has to do this. It means, of course, that someone must be in attendance during the whole 24 hours. The boilerman also oils the machine, about once each shift or something like that. There is a little

expense in that connection, but it is not considerable. As regards Mr. Gardner's other question about the costs, the Proctor Dryer is comparatively expensive. The cost of the machine that has been illustrated, with cars and pallets for 15,000 bricks a day, was approximately £6,000. The machine itself was somewhere about £2,000, but the expense is in the cars and pallets. We have two machines, so that there are 24 trucks in each machine at the same time. But although we have only 48 trucks in the dryer at any one time, we require to keep about 120 trucks in order to keep the place working. With goods of certain shapes, we have to choose a place to suit them in the kiln. We cannot set them just anywhere from top to bottom; and sometimes the kiln is not ready. A kiln does not always start off to a time schedule in the way that we can work the dryer. This means that we have a lot of goods standing about on cars. Coke-oven stuff necessarily has to be left standing about on the cars; it would never do to have it standing on the floor piled up. A good deal of capital is, therefore, sunk in the car equipment—more than in the machine itself.

MR. HOLLAND:—I understand Mr. Middleton is going to supplement this paper by Part 2, when he may be able to give us some reliable statistics.

MR. H. J. C. JOHNSTON:—Mr. Middleton does not tell us anything about the cost per thousand or per ton of drying these goods. Can he tell us approximately what this cost is?

MR. MIDDLETON:—I cannot very well do so. We have been running such mixtures that we have never run the machine on what we call its greatest efficiency. But the steam consumption is about 1,200 to 1,500 lbs. per hour; the steam pressure 80 and the steam temperature 325. We might have 15,000 bricks in the machine, or we might have 10,000 bricks and a big tonnage of lumps, and the tonnage of lumps is always changing. We can pack 2 tons of stuff on to the trucks when we are on 9 in. bricks, but we cannot pack the lumps closely together, and, consequently, there may be sometimes less than a ton. There is a good deal of empty space in the machine and it is much less efficient than when packed full of bricks. In fairness to the machine, I would say that the coal consumption costs would be much less if the machine were running on bricks alone. When running on our mixture of goods, it is roughly about 2 cwts. per thousand.

VIII.—Researches on the Theory of Fine Grinding.*

PART I.

Law governing the Connection between the Number of Particles and their Diameters in Grinding Crushed Sand.

By Geoffrey Martin, D.Sc., Ph.D., F.I.C., F. Inst. Phys., Chas. E. Blyth and Harold Tongue.

THE discovery of a simple law relating to continuity of particle-size in fine grinding (or the breaking up of larger into smaller particles) has long been a matter of scientific and technical importance.

By means of experiments extending over some years, the British Portland Cement Research Association has definitely ascertained that, so far as a crystalline substance such as "standard sand" is concerned, a definite law does undoubtedly exist, when this substance is ground in a tube mill.

Before going on to discuss this law, we must first state some of our definitions.

(1). *Definition of the statistical diameter of a particle as used in connection with the frequency curve.*

The diameter of a sphere is a clearly defined constant. If we consider a line drawn through it so as to divide it into two halves of equal apparent bulk, this line AB is called the *diameter* of the sphere. If measured in 1,000 different directions (*e.g.*, through CD) it will always be the same. (See Fig. 1.)

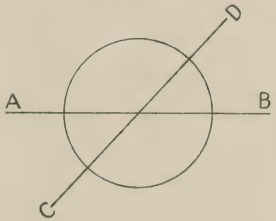


Fig. 1.

The diameter of a particle of irregular shape, like a crushed sand particle, differs in every direction and, therefore, is not so easily defined. It may, however, be defined as a *statistical* quantity as follows :—

Suppose we place a great number of particles of crushed sand on a microscopic slide provided with a very fine scale as shown in the illustration, Fig. 2.

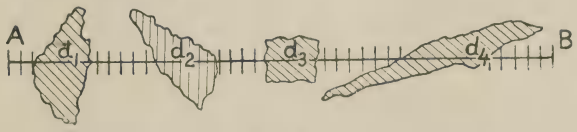


Fig. 2.

By viewing the particles under the microscope, we read off

* Printed by permission of The British Portland Cement Research Association.

the various diameters d_1, d_2, d_3, of the particles present, along the straight line AB along the scale, when this line seems to divide the particles into two portions of equal apparent bulk.

Now suppose we select at random out of all these particles, say, 1,000 of precisely the same apparent diameter d, and place them in a box. Then these 1,000 particles thus sorted out would form a *grade* whose *statistical diameter* is called d.

As the 1,000 particles lie in all sorts of haphazard directions, their diameters are measured, in the long run, with equal frequency in every direction, and, therefore, for the purpose of this enquiry, they may be considered as replaceable by 1,000 spherical particles of the same diameter d.

(2). *Definition of the Mean Diameter of a Particle as used in Connection with the Frequency Curve.*

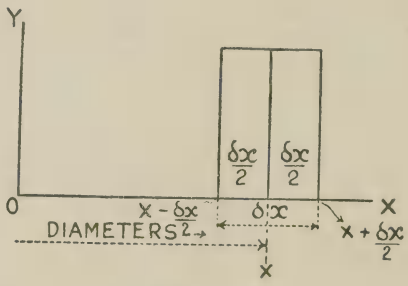


Fig. 3.

Let a weight W of sand be composed of N particles whose statistical diameters vary from O to x. (See Fig. 3.)

Imagine the particles sorted out in order of the magnitude of their statistical diameters. Let all the particles whose diameters vary from $x - \frac{\delta x}{2}$ to just under $x + \frac{\delta x}{2}$ be considered as all possessing the same diameter x.

Then x is defined to be the *mean diameter* of all particles with the range of diameter δx, x being the middle point of the range. The statement that the mean diameter is x, is meaningless unless the range δx is stated at the same time.

(3). *Construction of the Curve of Frequency.*

Suppose we have a weight W of sand composed of N particles whose *mean* diameters range from O to x in magnitude, δx being the range which decides the mean diameter. Imagine these N particles all arranged in order of magnitude of their mean diameters, along

a line OX which is numerically marked to correspond to the numerical value of the mean diameter. (Fig. 4).

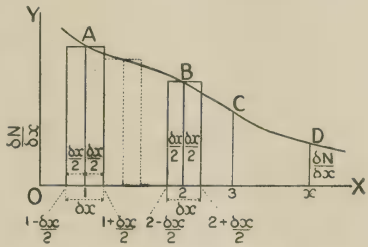


Fig. 4.

Thus at 1 is placed all those particles whose *statistical* diameters range from $1 - \frac{\delta x}{2}$ to just under $1 + \frac{\delta x}{2}$; at 2 are placed all those particles whose statistical diameters range from $2 - \frac{\delta x}{2}$ to just under $2 + \frac{\delta x}{2}$., and so on all up the scale.

Let there be δN_1 particles whose mean diameter is 1
δN_2 ,, ,, ,, ,, 2
δN_x ,, ,, ,, ,, x

At (1) erect an ordinate numerically equal to $\frac{\delta N_1}{\delta x}$

At (2) ,, ,, ,, ,, ,, ,, $\frac{\delta N_2}{\delta x}$

At x ,, ,, ,, ,, ,, ,, $\frac{\delta N_x}{\delta x}$

Join the points so obtained.

The line so obtained is the *frequency curve* and may be treated as a continuous curve, because intermediate points on it correspond to intermediate mean diameters.

To see that this is so, imagine again the N particles all arranged along the line OX in order of their *statistical* diameters (not *mean* diameters) and, as before, let AB be the interval δx which decides the mean diameter. (See Fig. 5.)

Then, in order to obtain the value of $\frac{\delta N_1}{\delta x}$ corresponding to a mean diameter x_1, we count all the particles whose statistical diameters occur *in the range* $A\ B = \delta x$. This number is δN_1. We divide δN_1 by the numerical value of $A\ B$ and we erect an ordinate

DC. at the mid point of $A\ B$ numerically equal to $\frac{\delta N_1}{A\ B}$. (See Fig. 5.)

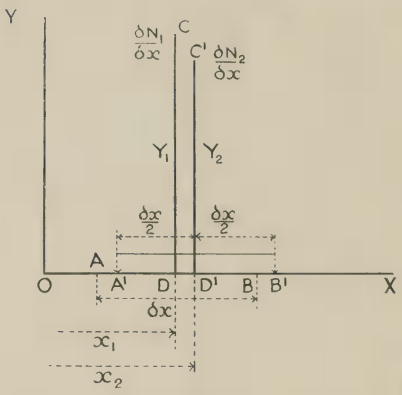


Fig. 5.

We can now repeat the same process for another equal interval A^1B^1 $(=A\ B)$ just slightly different from $A\ B$. Count the number of particles δN_2 which occur in the interval A^1B^1, and at D^1, the mid point of A^1B^1 we erect the corresponding ordinate numerically equal to $\frac{\delta N_2}{A^1B^1} = \frac{\delta N_2}{\delta x}$ and we get a second point C^1 on the curve very close to C. In fact, by taking the successive positions AB and A^1B^1 close enough together, we can make the successive points CC^1 as close together as we like, so that the curve of frequency may be considered a continuous one.

(4). *The Ordinates of the Frequency Curve represent the Speed of Increase in the Number of Particles for any Value of the Diameter.*

If we take any mean diameter x and erect an ordinate therefrom to cut the curve in A (Fig. 6), then the ordinate $Y_x = \frac{\delta N_x}{\delta x}$ so

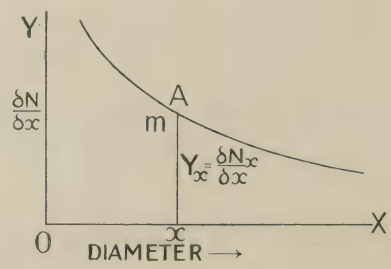


Fig. 6

that Y_x is *numerically equal to the instantaneous rate of increase in*

the number of particles per unit increase in diameter at the point where the mean diameter possesses the instantaneous value x. In other words, if the rate of increase in the number of particles N with the diameter x be maintained constant at the value it possessed when the mean diameter was x, then Y_x represents the number of particles which would be added to N when the diameter increased by unity.

On account of its importance in the theory of grinding, let us put this point in another way:—Let N be the total number of particles present in a sample of crushed sand (which previously had been graded and all the particles ranged in order of their diameters x). Let N_x be the number which includes all particles up to and embracing those possessing the mean diameter x. Now imagine the mean diameter x to be steadily increasing. Each small increase dx in the diameter x adds to N_x a number of particles. Now let x increase steadily to $x + 1$ and *let each equal increase dx* throughout the new range of diameter 1 *add the same number of particles to* N_x. This is equivalent to the statement that the *rate of increase* in the number of particles added to N_x with increase of diameter remains constant, while the mean diameter increased by unity, the *specified rate of increase* being the value which prevailed at the instant when the mean diameter was x. Then obviously the number of particles present when the diameter has increased from x to $x + 1$ is:—

$$N_x + \frac{\delta N}{\delta x} = N_x + Y_x$$

so that:—

$$\frac{\left(N_x + \frac{\delta N}{\delta x}\right) - N_x}{(x + 1) - x} = \frac{\delta N}{\delta x} = Y_x$$

or in words:—Number of particles when the diameter is $x + 1$ less the number of particles when the diameter is x, gives the ordinate of frequency curve at point x (on the assumption that no change in speed of increase occurred while the diameter increased by unity).

(5). *The Area embraced by the Frequency Curve between the Mean Diameters x_1 and x_2 is numerically equal to the Number of Particles comprised between those Limits of Diameter.*

That is, in Fig. 7, if MN is the frequency curve, OX represents the diameters, and OY represents $\frac{\delta N}{\delta x}$, then the *area* $x_1 M N x_2$ is *numerically equal* to the number of particles whose diameters range from x_1 to just under x_2.

For, in the small range of diameter δx, there occur δN particles whose mean diameter is x, or in the range 1, the number of particles

would be $\frac{\delta N}{\delta x}$ (assuming constancy of increase during the interval 1) or in the small range dx the number of particles is

$$dN = \frac{\delta N}{\delta x}.dx \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\text{or } N_{x_1}^{x_2} = \int_{x_1}^{x_2} \frac{\delta N}{\delta x}.dx \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Here $N_{x_1}^{x_2}$ represents the total number of particles which occur between the ranges of diamerer x_1 and x_2 in a given weight W of crushed sand composed in all of N particles.

If now $A\ B$ equals $\frac{\delta N}{\delta x}$ at the point where the mean diameter is x_1, and $c\ d$ represents dx, then the shaded area $c\ d\ f\ e = AB \times dx = \frac{\delta N}{\delta x}.dx = dN$.

so that

$$N_{x_1}^{x_2} = \int_{x_1}^{x_2} \frac{\delta N}{\delta x} dx = \textit{area } x_1 M N x_2$$

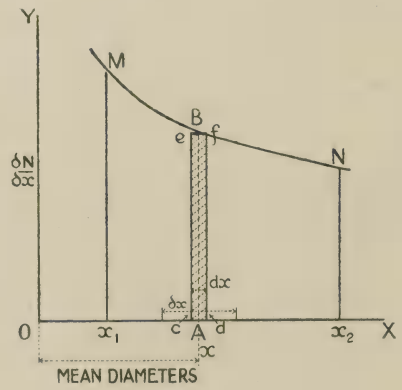


Fig. 7.

(6). *Conclusions drawn from a Study of the Frequency Curves for Crushed Sand.*

We will now state the conclusions that we have derived from the study of numerous experimental frequency curves connecting the number of particles with their diameter when Leighton

Buzzard standard sand is crushed in an 18″×18″ experimental tube mill.

The experimental data on which these conclusions are founded will be set forth in detail below and the reader can verify the conclusions by making a careful study of the experiments.

(7). *The Frequency Curve follows the Compound Interest Law.*

In every case yet tried the equation of the frequency curve for crushed sand possesses the form :—

$$y = a.e.^{-bx} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where y represents the numerical value of $\frac{\delta N}{\delta x}$ (the rate of increase in the number of particles per unit increase of diameter at the point where the mean diameter is x) and a and b are constants depending on the sample of sand treated.

If in any physical investigation we find that we are dealing with an experimental function, y, of this nature, we know that the function y is varying at a rate proportional to itself. This is the well-known "Compound Interest Law" and will be referred to at length below. The curve has the form shown in Fig. 8.

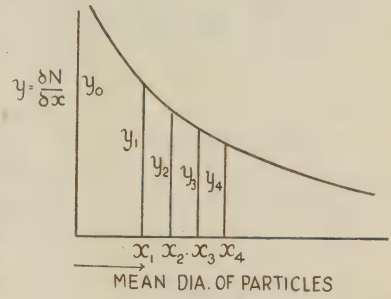


Fig. 8.

In (1) let $x=o$

$$\text{Then } y_0 = a.e^0 = a = \frac{\delta N_0}{\delta x}$$

so that a signifies the speed of increase in the number of particles per unit increase in diameter at the point where the mean diameter is zero in a sample of sand weighing W and composed of N particles.

To find b, at any point on the curve corresponding to two successive mean diameters x_1 and x_2 which differ by unity (*i.e.*, $x_2 - x_1 = 1$) find the two corresponding ordinates y_1 and y_2.

$$\text{Then } y_1 = a.e^{-bx_1}$$
$$y_2 = a.e.^{-bx_2}$$

$$\text{or } \frac{y_1}{y_2} = \frac{a.e.^{-bx_1}}{a.e.^{-bx_2}} = e^{b(x_2 - x_1)}$$

$$\frac{y_1}{y_2} = e^b, \text{ since } x_2 - x_1 = 1.$$

$$\text{Hence } b = log_e \frac{y_1}{y_2}$$

$$b = 2{\cdot}3026 \; log_{10} \frac{y_1}{y_2}$$

a has little practical importance since it merely depends on the quantity of sand we are examining.

b (or rather e^b) is a characteristic number peculiar to the sand as explained below.

(8). *The Logarithms of the Frequencies plotted against the Mean Diameters give a Straight Line.*

If we plot the values of $\log_e y = \log_e \frac{\delta N}{\delta x}$ as ordinates against the corresponding mean diameters x as abscissae, then we invariably obtain a straight line A B as shown in Figs. 9 and 10. This fact

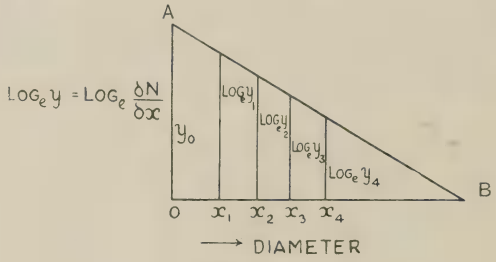


Fig. 9.

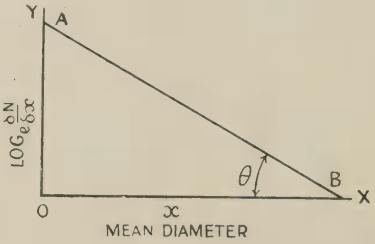


Fig. 10.

enables us to determine rapidly the equation of the straight line AB and so to obtain the numerical values of the two constants a and b for any given case, thus :—

Since $\frac{\delta N}{\delta x} = a.e.^{-bx}$

$$\therefore \log_e \frac{\delta N}{\delta x} = \log_e a - bx \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

This is the equation of a straight line AB.

To find a, let $x = 0$: then $\log_e a = \log_e \frac{\delta N}{\delta x_0}$ (where $x = 0$); or $\log_e a = OA$, whence a can be determined.

To find b, put $\log_e \frac{\delta N}{\delta x} = O$ and write OA for $\log_e a$.

then $x = OB$ at this point and (1) becomes
$OA - b.\ OB = O$

or $b = \frac{OA}{OB} = tan\ \theta$

(10). *In the Frequency Curve successive Equidistant Ordinates bear a Constant Ratio to each other.*

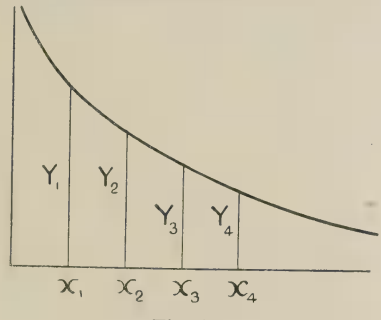


Fig. 11.

If we take equidistant successive ordinates Y_1, Y_2, Y_3, Y_4, (See Fig. 11), and divide each one by the following ordinate, we find that a constant number is obtained thus :—

$$\frac{Y_1}{Y_2} = \frac{Y_2}{Y_3} = \frac{Y_3}{Y_4} = \frac{Y_5}{Y_6} = \text{Constant } M$$

This at once follows from the equation for Y, viz. :—

$$Y = a.e^{-bx}$$

Then $Y_1 = a.e^{-bx_1}$ or $\frac{Y_1}{Y_2} = e^{b(x_2 - x_1)}$

$Y_2 = a.e^{-bx_2}$ or $\frac{Y_2}{Y_3} = e^{b(x_3 - x_2)}$

$Y_3 = a.e^{-bx_3}$ or $\frac{Y_3}{Y_4} = e^{b(x_4 - x_3)}$

$Y_4 = a.e^{-bx_4}$

If now we choose $x_2 - x_1 = x_3 - x_2 = x_4 - x_3 =$ constant K, it follows that :—

$$\frac{Y_1}{Y_2} = \frac{Y_2}{Y_3} = \frac{Y_3}{Y_4} = e^{b \cdot K} = \text{constant.}$$

Hence, knowing e^{bK} and the value of any one ordinate, we can calculate the value of any other of these equidistant ordinates.

For obviously :—

$Y_1 = e^{bK}.\ Y_2 = e^{2bK}.\ Y_3 = e^{3bK}.\ Y_4 = \ldots\ldots = e^{n \cdot bK} Y_{n+1}$

(11). *The Numbers of Particles contained between Successive Equidistant Diameters bear a Constant Ratio to each other* :

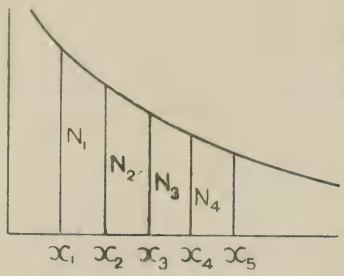


Fig. 12.

If N_1, N_2, N_3, N_4 be the number of particles comprised between the equidistant diameters x_1, x_2, x_3, x_4, and x_5 (Fig. 12),

$$\text{then } \frac{N_1}{N_2} = \frac{N_2}{N_3} = \frac{N_3}{N_4} = \text{constant.}$$

This is a conclusion of considerable practical importance and may be proved as follows :—

Let $x_2 - x_1 = x_3 - x_2 = x_4 - x_3$ etc. $=$ constant K.

Then $x_3 = K + x_2$
and $x_2 = K + x_1$
$\therefore x_3 = 2K + x_1$ .....(1)

$$\text{Also } \frac{N_1}{N_2} = \frac{\int_{x_1}^{x_2} a.e^{-bx}.dx}{\int_{x_2}^{x_3} a.e^{-bx}.dx} = \frac{\frac{a}{b}\left(e^{-bx_1} - e^{-bx_2}\right)}{\frac{a}{b}\left(e^{-bx_2} - e^{-bx_3}\right)}$$

$$= \frac{e^{-bx_1} - e^{-b\,(K + x_1)}}{e^{-b\,(K + x_1)} - e^{-b\,(2K + x_1)}}$$

$$= \frac{e^{-bx_1} - e^{-bx_1}\,e^{-bK}}{e^{-bx_1}\,e^{-bK} - e^{-b\cdot x_1}\,e^{-2bK}}$$

$$= \frac{e^{-bx_1}\,(1 - e^{-bK})}{e^{-bx_1}\,(e^{-bK} - e^{-2bK})}$$

$$= \frac{1 - e^{-bK}}{e^{-bK}\,(1 - e^{-bK})}$$

$$= \frac{1}{e^{-bK}}$$

$$= e^{bK} = \textit{a constant.}$$

Similarly

$$\frac{N_2}{N_3} = e^{bK} \qquad \frac{N_3}{N_4} = e^{bK} \qquad \frac{N_n}{N_{n+1}} = e^{bK}$$

So that :—

$$\frac{N_1}{N_2} = \frac{N_2}{N_3} = \frac{N_3}{N_4} = \ldots \frac{N_n}{N_{n+1}} = \textit{constant } e^{bK}$$

$$\therefore N_1 = N_2.e^{bK} = N_3.e^{2bK} = N_4.e^{3bK} \ldots\ldots = N_{n+1}e^{nbK}$$

So that, knowing the number of particles between any two equidistant diameters, we can calculate the number of particles between *any other pair of equidistant diameters* anywhere up or down the scale.

The importance of this conclusion is obvious in the question of choosing the mesh apertures of successive sieves.

If the differences in the successive mesh apertures were equal all down the scale, a simple calculation should allow us to calculate the number of particles passing through any one sieve and remaining on the next successive one, on any one of the sieves, large or small.

(12). *Calculation of the Number of Particles of Sand which occur between Definite Ranges of Diameter.*

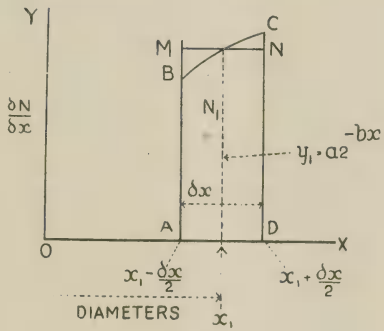


Fig. 13.

It has been proved above that *the area of the frequency curve comprised between the mean diameters x_1 and x_2 is equal numerically to the number of particles between these limits of diameter.*

Since $\dfrac{\delta N}{\delta x} = a.e.^{bx}$

the *total number* of particles in the sample of sand is:—

$$N_o^\infty = \int_o^\infty a.e.^{-bx}dx = \frac{a}{b} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

The total number between any two limits of diameter x_1 and x_2 is

$$N_{x_1}^{x_2} = \int_{x_1}^{x_2} a.e.^{-bx}.dx = \left[-\frac{a}{b}.e^{-bx} \right]_{x_1}^{x_2}$$

$$= \frac{a}{b}\left[e^{-bx} \right]_{x_2}^{x_1} = \frac{a}{b}\left(\frac{1}{e^{bx_1}} - \frac{1}{e^{bx_2}} \right) \ldots\ldots \quad (4)$$

So that, knowing a and b in the case of any one sample of sand, we

can calculate any data relating to the numbers of particles in any one grade of sand.

The *total number* of particles of sand between the diameters o and x is

$$\underset{o}{\overset{x}{N}} = \int_o^x a.e.^{-bx}dx = \frac{a}{b}\left(1 - \frac{1}{e^{bx}}\right) \quad \ldots\ldots\ldots\ldots \quad (5)$$

The rate of increase of the number of particles is obviously from (5)

$$\frac{dN}{dx} = a.e^{-bx} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

and will be a *maximum* when $x = o$ and will be xero when $x = \infty$

Practical Example. A sample of ground sand was placed on a microscopic slide and examined under a microscope, It was found by actual counting that to every particle of mean diameter 7×10^{-4} inches there occurred two particles of mean diameter 6×10^{-4} inches Also 100 particles occurred between the range of diameter $6{\cdot}5 \times 10^{-7}$ and $7{\cdot}5 \times 10^{-7}$ inches. Calculate (1) the number of particles present ranging between 3×10^{-4} and 7×10^{-4} inches. (2). The total number of particles present of all diameters.

Here the unit of length is taken as 1×10^{-4} inch.

$$e^b = \frac{y_1}{y_2} = \frac{2}{1}$$

or $b = \log_e 2 = 2{\cdot}3026 \times \log_{10} 2 = 0{\cdot}69315.$

$$\text{also } \frac{\delta N}{\delta x} = \frac{100}{7{\cdot}5 - 6{\cdot}5} = 100.$$

$$\text{But } \frac{\delta N}{\delta x} = a.e^{-bx} = \frac{a}{(e^b)^x} = \frac{a}{2^x}$$

Also at this point x (the mean diameter) is 7

$$\text{Hence } \frac{a}{2^7} = 100, \text{ or } a = 100 \times 2^7$$

Hence the total number of particles present in the sample examined is :—

$$\underset{o}{N^\infty} = \frac{a}{b} = \frac{100 \times 2^7}{0{\cdot}69315} = \frac{12800}{0.69315} = 18{,}470$$

Also the number of particles present between the two limits of diameters 3×10^{-4} inch and 7×10^{-4} inch is

$$\underset{3}{N^7} = \frac{a}{b}\left(\frac{1}{e^{bx_1}} - \frac{1}{e^{bx_2}}\right) = 18{,}470\left(\frac{1}{2^3} - \frac{1}{2^7}\right)$$

$$= 18{,}470 \times \frac{128 - 8}{8 \times 128} = 2164$$

So that out of a total of 18,470 particles, 2164 occur between the limits of 3×10^{-4} inches and 7×10^{-4} inches.

(13). *Significance of the Compound Interest Law of Particle Size.*

The results in the preceding pages show that if, in a given weight W of finely crushed sand, there occur N particles of mean diameter x*, and if N and x be considered variables, then in every case so far tested :—

$$N = a.e^{-bx} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where a and b are two constants characteristic of the particular sample tested.

Differentiating (1) we obtain :—

$$\frac{dN}{dx} = -b.ae^{-bx} = -b.N., \text{ or } -\frac{dN}{dx} = b.N.$$

In other words, *the instantaneous rate of increase with decrease in diameter, of the number particles present of any given mean diameter x, is proportional to the number of particles present of that size at the instant when the speed of increase was measured, i.e.,* the number N increases at a rate proportional to itself.

It should be borne in mind that, when we say that N is the number of particles of mean diameter x, we mean that the sand is supposed to be sorted out into its component particles, which are arranged according to the magnitude of their diameters, and N is the number of particles lying in a compartment in which are placed all particles of a diameter ranging from $x - \delta x$ to just under $x + \delta x$ (δx being small compared to x). These are all grouped together as possessing the same mean diameter x. The limits of diameter $\pm\ \delta x$ must, of course, be taken the same for every value of x up or down the scale of diameters, otherwise the numbers N_1 of a given mean diameter x_1 would not be strictly comparable to the numbers N_2 of a mean diameter x_2, as they would be taken for two different limits of diameter δx_1 and δx_2. The number N of particles of the mean diameter x, therefore, is a particular case of section 11 where the equidistant diameters are connected by the relationship $x_2 - x_1 = x_3 - x_2 =$ etc., $= \delta x$, and in Fig. 13 $N_1 =$ *area A B C D*

$$= \int_{x_1 - \frac{\delta x}{2}}^{x_1 + \frac{\delta x}{2}} a.e^{-bx1}dx = \frac{a}{b}.e^{bx1}\left[e^{b\frac{\delta x}{2}} - e^{-b\frac{\delta x}{2}}\right]$$

$$= \frac{a.e^{bx1}}{b}\left[\left(1 + b.\frac{\delta x}{2} + \frac{b^2(\delta x)^2}{8} + \ldots\right) - \left(1 - b.\frac{\delta x}{2} + \frac{b^2(\delta x)^2}{8}\right)\right]$$

$$= \frac{a.e^{bx1}}{b.}(b\delta x - etc.)$$

* See § 11.

$= a.e^{-bx}{}_1 \delta x$ (Since x is very small and $b<1$ in all usual cases)
or $N_1 = y_1\ \delta x$ = area $A\ M\ N\ D$.

Similarly $N_2 = y_2\ \delta x$ $\quad N_3 = y_3\ \delta x$.

$$\text{So that } \frac{N_1}{N_2} = \frac{y_1\ \delta x}{y_2\ \delta x} = \frac{y_1}{y_2} = e.^{-b\cdot\delta x}$$

$$\frac{N_2}{N_3} = \frac{y_2\ \delta x}{y_3\ \delta x} = \frac{y_2}{y_3} = e^{-b\cdot\delta x}$$

$$\text{So that } \frac{N_1}{N_2} = \frac{N_2}{N_3} = \frac{N_3}{N_4} = \text{etc.} = e^{-b\delta x}.$$

A great many natural phenomena possess this property. Since money lent at compound interest increases in this way, the above property has been styled by Lord Kelvin "The Compound Interest Law."*

Since the rate of growth of the number of particles with decrease of diameter follows the compound interest law, it is quite a simple matter to calculate the number of particles present of any given mean diameter whatsoever, and also the total number of particles present in the whole—or any part of the sample—merely by knowing the number of particles present of one particular grade and the constant b, which we will call the characteristic or family number of the sand.

This is a considerable advance.

The law is probably the expression of the fact that crystals have a definite and fixed structure, and consequently break up when subjected to percussion or pressure in the same regular and definite manner all down the scale of magnitude, a definite mathematical law being followed when the number of particles is sufficiently numerous to allow of the application of the law of probability thereto.

No matter whether the particles are large or small, they break down in the same manner all down the scale. So that the products of the break down of one of the smallest particles would, if magnified sufficiently, be an image of the products produced by the breakdown of one of the larger particles.†

(14). *Illustrations of the Compound Interest Law of Particle Size.*

Let us illustrate by means of a few examples the meaning of this "Compound Interest Law."

Consider a set of sand particles (See Fig. 14) called grade A whose mean diameter is d_1. Now imagine the particles comprising A to be shattered by grinding into a series of smaller particles (Grade B), whose mean diameter is d_2, and let B in its turn be shattered into a third series of smaller particles C of an equidistant

* cf. Mellor. *Higher Mathematics*. (1919) p. 56.

† Any phenomena in which this occurs must follow a law expressed by an exponential curve, the mathematical reason being that e^x is the only function which, when differentiated or integrated, remains unchanged.

mean diameter d_3 (*i.e.*, $d_3 - d_2 = d_2 - d_1$), and let grade C in its turn be shattered into the still smaller particles D of the equidistant diameter d_4 (*i.e.*, $d_4 - d_3 = d_3 - d_2$) and so on all down the scale.

Each set of particles is, so to speak, the parent of the next set.

There the law asserts that each of these particles generates a family of smaller particles of the same number all down the scale

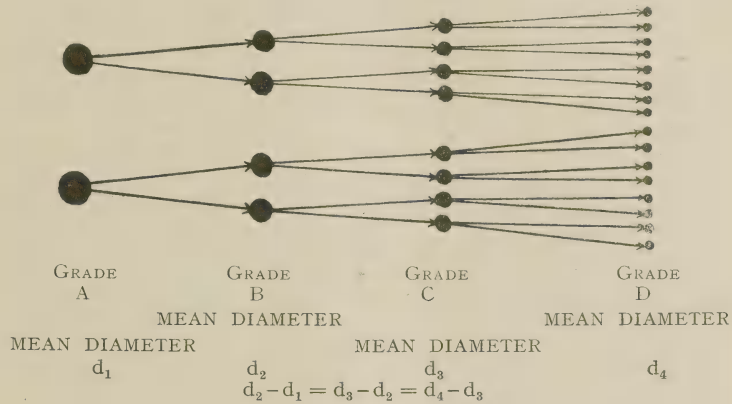


Fig. 14.

of size. That is, by grinding each of the particles A gives rise to the same number k (in our illustration $k = 2$) of smaller particles B, each of which in its turn gives rise to the same number k of still smaller particles C, and so on all down the scale so far as we can pursue the matter by means of the microscope, with the ultimate production of colloidal particles.

Of course, we are speaking in a *statistical sense* when we say that *each* particle of, say, grade A gives rise to the same number k of smaller particles of grade B. Some of the particles in A may give rise to more than k and others to less than k of B, but in the long run, if we took a large number, say, 10,000 of A, then we would find very nearly $10{,}000 \times k$ of the variety B, $10{,}000k^2$ of C and $10{,}000k^3$ of D, each grade sub-dividing at the same rate for equal decrements of diameter, and this rate does not increase or diminish as we go down the scale of size, but keeps constant for one particular sample of sand.

We are, of course, speaking figuratively when we say that the particles of grade A are the "parents" of the particles B. The one set of particles are not the *sole* or *direct* parents of the other sets. There are many steps in between. In fact, a single one of the particles composing A on receiving a blow will break up into a succession of smaller particles of diameters varying widely all down the scale, so that in addition to producing some of the particles composing B, the same particle will simultaneously contribute

to the heaps of particles represented by C, D, and others of intermediate diameters.

The essential point of the whole scheme is that each set of particles breaks down in the same way, so that the product produced by the break down of a small particle like D, is, if sufficiently magnified, merely an image of the product produced by the break down of a large particle like A.

(15). PRACTICAL EXAMPLE.

Let us illustrate the law by a numerical example which, although fictitious, follows the mathematical procedure adopted in the experimental part below and so will aid the reader in studying this part of the paper.

Suppose there are 100 particles of mean diameter 7×10^{-4} inches. Suppose each of these to give rise to 2 smaller particles 6×10^{-4} inches in mean diameter and each of these in turn to give rise to 2 smaller ones of mean diameter 5×10^{-4} inches, and so on all down the scale, always diminishing the diameter from one grade to the next by 1/10,000 part of an inch. (1×10^{-4} inch).

There is thus constructed the following table :—

TABLE 1.

I. Mean diameter of particles in inches	II. Scale taken in diagram to represent diameters	III. No. of particles of mean diameter d	IV. $\text{Log}_{10} N$.	V. $\text{Log}_e N$. $= 2{\cdot}3026\ \text{Log}_{10} N$.
d	$d \times 10^4$	N		
7×10^{-4}	7″	$N_7 = 100 \times 1 = 100$	2·0000	4·605
6×10^{-4}	6″	$N_6 = 100 \times 2 = 200$	2·3010	5·298
5×10^{-4}	5″	$N_5 = 200 \times 2 = 400$	2·6021	5·992
4×10^{-4}	4″	$N_4 = 400 \times 2 = 800$	2·9031	6·634
3×10^{-4}	3″	$N_3 = 800 \times 2 = 1600$	3·2041	7·378
2×10^{-4}	2″	$N_2 = 1600 \times 2 = 3200$	3·5051	8·071
1×10^{-4}	1″	$N_1 = 3200 \times 2 = 6400$	3·8062	8·865

Using this table, perform the following operations :—

(1) Divide the successive values of N one into the other :—

$$\frac{N_1}{N_2} = \frac{6400}{3200} = 2. \qquad \frac{N_4}{N_5} = \frac{800}{400} = 2$$

$$\frac{N_2}{N_3} = \frac{3200}{1600} = 2. \qquad \frac{N_5}{N_6} = \frac{400}{200} = 2$$

$$\frac{N_3}{N_4} = \frac{1600}{800} = 2 \qquad \frac{N_6}{N_7} = \frac{200}{100} = 2$$

So that $\frac{N_1}{N_2} = \frac{N_2}{N_3} = \frac{N_3}{N_4} = \frac{N_4}{N_5} = \frac{N_5}{N_6} = \frac{N_6}{N_7} = 2.$

We need not, of course, confine ourselves to intervals of diameter which decrease by unity (*i.e.*, 1×10^{-4} inch) as in the above case. Any *constant difference* of diameters will produce the same result, although the constant will differ for each interval of diameter chosen.

For example, if we take the numbers corresponding to mean diameters which differ by two units (*i.e.*, by 2×10^{-4}) from each other, we get the following table :—

$$\frac{N_1}{N_3} = \frac{6400}{1600} = 4.$$

$$\frac{N_3}{N_5} = \frac{1600}{400} = 4.$$

$$\frac{N_5}{N_7} = \frac{400}{100} = 4.$$

So that again $\frac{N_1}{N_3} = \frac{N_3}{N_5} = \frac{N_5}{N_7} = 4.$

We thus see that we always obtain a *constant ratio* between successive values of N, provided that the successive mean diameters are *equidistant*, but that the exact value of the ratio depends upon the intervals of diameter chosen.

(2). Next, from the above Table 1, plot the logarithms (preferably the logs to base e) against the diameters, *i.e.*, plot column V against column II, and we see that we obtain a straight line, AB (Fig. 15) exactly as found in the experimental part detailed below.

A comparison of this straight line with the original curve at once shows how very much more convenient it is to plot against the diameter the logarithms of the frequencies N, rather than the actual values of N, because we can extend the resulting straight line in any direction by means of a ruler, and thus very easily interpolate for values of d and N which we cannot directly measure, whereas to perform a similar operation for the curve itself easily leads to serious errors.

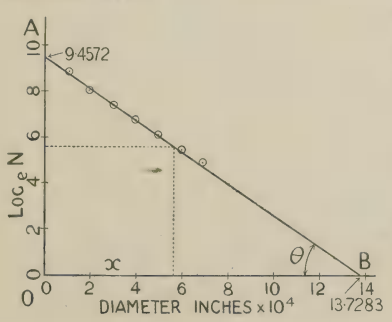


Fig. 15.

The equation of the straight line AB is :—

$$\frac{\text{Log}_e N}{OA} + \frac{x}{OB} = 1.$$

$$\text{or } \text{Log}_e N = OA - \frac{OA}{OB} x \quad \ldots (1)$$

Also if $N = a.e^{-bx}$

$\text{Log}_e N = \log_e a - b.x \ldots\ldots (2)$

So that $OA = \log_e a$

$$b = \frac{OA}{OB}$$

By actual measurement on an enlarged drawing (Fig. 15)

$OA = 9{\cdot}4572 = \log_e 12800$

$OB = 13{\cdot}6438$

$$\therefore \quad b = \frac{OA}{OB} = 0{\cdot}69315 = \log_e 2.$$

So that $a = 12800$

$b = 0{\cdot}69315$ and $e^b = 2$.

Experimental Part.

(16). *Description of Apparatus used in Preliminary Experiments.*

The original object of the experiments was to ascertain the average size of a crushed sand particle which would be supported by a steady blast of air travelling with a fixed velocity in a brass tube. For this purpose white standard Leighton Buzzard Sand, graded by passing through the 20 mesh cement sieve and being retained on the 30 mesh cement sieve, was ground in an 18″ experimental tube mill (13·9 lbs. of sand to 247 lbs. of 1″ steel balls) for various lengths of time, a sample was removed, subjected

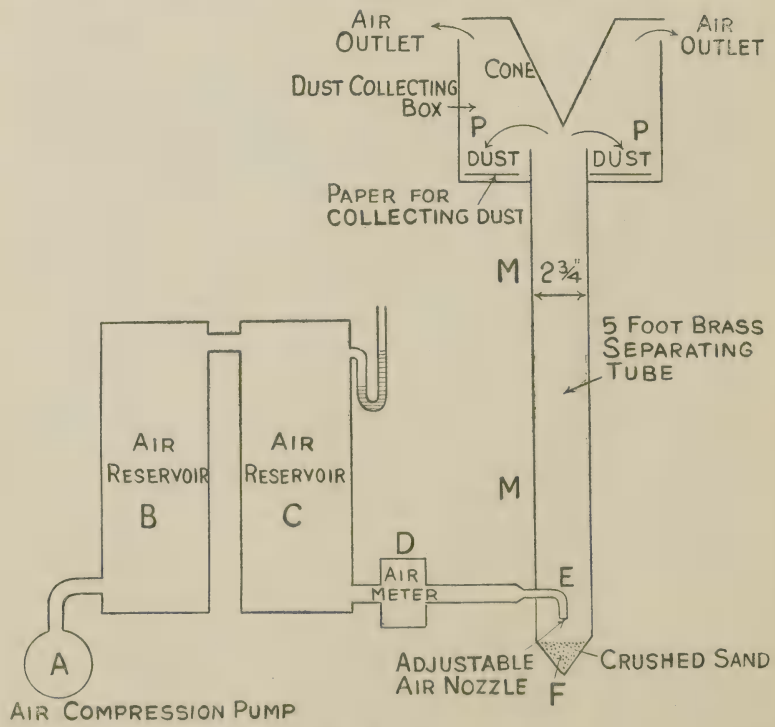


Fig. 16.

to the air elutriation process, and the dust coming out of the top of the tube was caught at various intervals of time and examined under the microscope. The apparatus used is shown diagrammatically in Fig. 16.

About 25 grams of sand were placed at the bottom F of a 5-foot brass tube MM ($2\frac{3}{4}''$ int. diam.) and subjected to an air blast from an adjustable small nozzle E (aperture 0·060 inch). The air pressure was 40 cms. of water. The dust separated from the sand was collected on strips of paper placed in the collecting box P.

It was soon seen that there was a connection between the number of particles and their diameters, with apparently a curious maximum point in each case which merited further research. The following results showed this.

(17). *Preliminary Experiments showing Apparent Maximum of Frequency Curve.*

A slide was prepared, under cover glass, of particles removed during the first 15 minutes of the air elutriation. The diameters were examined by a Watson "Praxis" microscope, using $\frac{1}{6}$ inch objective and extension 7, 45 divisions of the scale being found equal to 0·005 inch, or 1 division $= 1{\cdot}111 \times 10^{-4}$ inch.

In all 528 particles were measured, and divided into groups as shown in Table 2 below.

TABLE 2.

I. Range of diameters in divisions. (1 div. = $1{\cdot}111 \times 10^{-4}$ inch.	II. Mean of range. (divs.)	III. Value of mean (inches)	IV. No. of particles in range
0·25 – 0·75	0·5	$0{\cdot}5555 \times 10^{-4}$	84
0·75 – 1·25	1·0	$1{\cdot}111 \times 10^{-4}$	208
1·25 – 1·75	1·5	$1{\cdot}666 \times 10^{-4}$	84
1·75 – 2·25	2·0	$2{\cdot}222 \times 10^{-4}$	72
2·25 – 2·75	2·5	$2{\cdot}777 \times 10^{-4}$	20
2·75 – 3·25	3·0	$3{\cdot}333 \times 10^{-4}$	34
3·25 – 3·75	3·5	$3{\cdot}8888 \times 10^{-4}$	6
3·75 – 4·25	4·0	$4{\cdot}444 \times 10^{-4}$	5
4·25 – 4·75	4·5	$5{\cdot}000 \times 10^{-4}$	3
4·75 – 5·25	5·0	$5{\cdot}555 \times 10^{-4}$	5
5·50 – 6·50	6·0	$6{\cdot}666 \times 10^{-4}$	4
6·50 – 7·50	7·0	$7{\cdot}777 \times 10^{-4}$	2
7·50 – 8·50	8·0	$8{\cdot}888 \times 10^{-4}$	1
			528

Curve *ABC* (Fig. 17) plotted from columns III and IV of Table 2, shows the relation between the numbers of the particles and the diameter of the particles.

This curve *ABC* is constructed as follows:—Out of 528 particles measured, there were 208 particles of diameters between 0·75 and 1·25 microscopic divisions. The mean of 0·75 and 1·25 is 1·0 microscopic divisions.

We accordingly take this mean division 1·0 as abscissa and erect as ordinate the number of particles corresponding to this mean

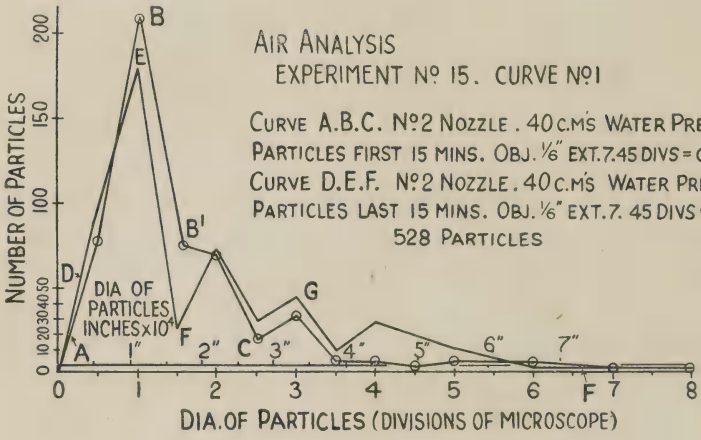


Fig. 17.

diameter, viz.: 208. This is the point B. The next point B^1 is similarly obtained by counting the number of particles between 1·25 and 1·75 divisions diameter. This number is 84. Taking 1·5 as the mean abscissa we erect the ordinate $B^1 = 84$, and so on.

The curve *DEFG*, (Fig. 17) was similarly constructed from a microscopic slide obtained during the last 15 minutes of experiment 15. The data on the microscopic slide from which the curve was obtained are given in the table 3 below.

TABLE 3.

I. Range of diam. in divisions (1 div. = 1·111 × 10^{-4} inch.)	II. Mean of range	III. Value in inches	IV. No. of particles in range
0·25 – 0·75	0·5	0·5555 × 10^{-4}	91
0·75 – 1·25	1·0	1·111 × 10^{-4}	181
1·25 – 1·75	1·5	1·666 × 10^{-4}	33
1·75 – 2·25	2·0	2·222 × 10^{-4}	76
2·25 – 2·75	2·5	2·777 × 10^{-4}	32
2·75 – 3·25	3·0	3·333 × 10^{-4}	46
3·25 – 3·75	3·5	3·8888 × 10^{-4}	16
3·75 – 4·25	4·0	4·4444 × 10^{-4}	31
4·25 – 4·75	4·5	5·0000 × 10^{-4}	0
4·75 – 5·25	5·0	5·555 × 10^{-4}	15
5·5 – 6·5	6·0	6·666 × 10^{-4}	3
6·5 – 7·5	7·0	7·777 × 10^{-4}	3
7·5 – 8·0	8·0	8·888 × 10^{-4}	1
			528

In each case the maximum number of particles corresponds to a diameter of 1 division $= 1{\cdot}111 \times 10^{-4}$ inch.

The arithmetical average diameter of particles removed during the first 15 minutes of the experiment was 0·000170″, and during the last 15 minutes 0·000195.

A curious effect is the regular increase and decrease of the number of particles observed as we pass down the scale. There are always a larger number of particles of 1, 2, 3, 4 or any whole number of divisions than correspond to intermediate divisions, such as 1·5, 2·5, 3·5, etc. This is a psychological effect which always makes its appearance in curves of this character, and is eliminated by taking a mean curve which we will do later. (See for example Figs. 18 and 20).

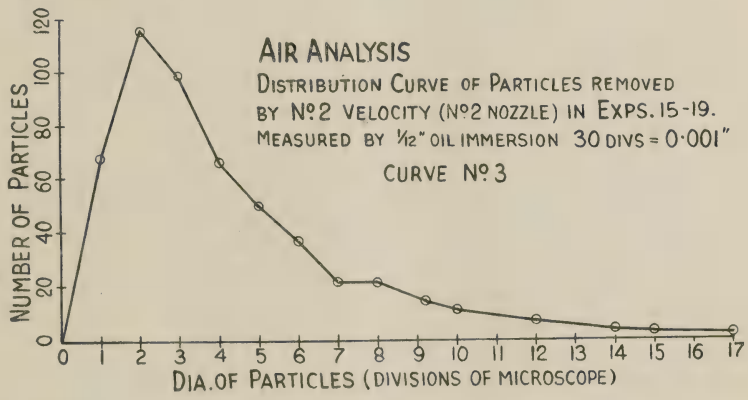


Fig. 18.

(18). *Apparent Maximum Points of Frequency Curves shown to vary with the Magnification Employed in the Measuring Microscope.*

In the two curves *ABC* and *DEFG* of Fig. 17, above discussed, it will be seen that as the magnitude of the mean diameter decreases, the number of particles rapidly increases, until a maximum is attained. Thereafter a rapid decrease sets in.

The question now arises, does this maximum value correspond to a true physical reality, or is it not rather due to the fact that, when the size of the particles falls below a certain magnitude, the microscope eyepiece will not detect them? So that the maximum value observed depends upon the power of the objective used? For example, with the $\frac{1}{6}''$ objective, it was extremely difficult to enumerate particles below 1·5 divs. diameter (*i.e.* $1{\cdot}5 \times 1{\cdot}111 \times 10^{-4} = 1{\cdot}67 \times 10^{-4}$ inch) and particles of, say, $0{\cdot}5 \times 10^{-4}$ inch diameter could scarcely be seen and so would escape enumeration altogether.

It seems natural to suppose that as the diameter of the particles decreases the number corresponding thereto should increase, and

that, therefore, no maximum should occur until practically molecular dimensions were arrived at—a point far beyond the resolving power of the microscope.

In order to test this point the work was repeated with a more powerful microscopic objective—viz., a $\frac{1}{12}''$ oil immersion lens.

For this purpose the particles removed during the whole of experiments 15—19 were well mixed and four slides were prepared under cover glasses and examined, first of all by the $\frac{1}{12}''$ oil immersion lens and then by the $\frac{1}{6}''$ objective ext.7 as used above.

The results are shown in Tables 4 and 5.

Table 4.
Experiments 15-19.

Particles removed during the whole period of elutriation during experiments 15-19 inclusive measured by 1/12″ *oil immersion lens.* 30 divs. = 0·001″

I. Range of diam. in divisions of microscope	II. Mean of range in divisions of microscope	III. Value of mean inches	IV. No. of particles measured
0·5 – 1·5	1	$0{\cdot}333 \times 10^{-4}$	65
1·5 – 2·5	2	$0{\cdot}667 \times 10^{-4}$	110
2·5 – 3·5	3	$1{\cdot}00 \times 10^{-4}$	94
3·5 – 4·5	4	$1{\cdot}33 \times 10^{-4}$	63
4·5 – 5·5	5	$1{\cdot}67 \times 10^{-4}$	48
5·5 – 6·5	6	$2{\cdot}00 \times 10^{-4}$	36
6·5 – 7·5	7	$2{\cdot}33 \times 10^{-4}$	21
7·5 – 8·5	8	$2{\cdot}67 \times 10^{-4}$	21
8·5 – 9·5	9	$3{\cdot}00 \times 10^{-4}$	14
9·5 – 10·5	10	$3{\cdot}33 \times 10^{-4}$	11
10·5 – 11·5	11	$3{\cdot}67 \times 10^{-4}$	0
11·5 – 12·5	12	$4{\cdot}00 \times 10^{-4}$	7
12·5 – 13·5	13	$4{\cdot}33 \times 10^{-4}$	0
13·5 – 14·5	14	$4{\cdot}67 \times 10^{-4}$	3
14·5 – 15·5	15	$5{\cdot}00 \times 10^{-4}$	3
15·5 – 16·5	16	$5{\cdot}33 \times 10^{-4}$	0
16·5 – 17·5	17	$5{\cdot}67 \times 10^{-4}$	2
			498

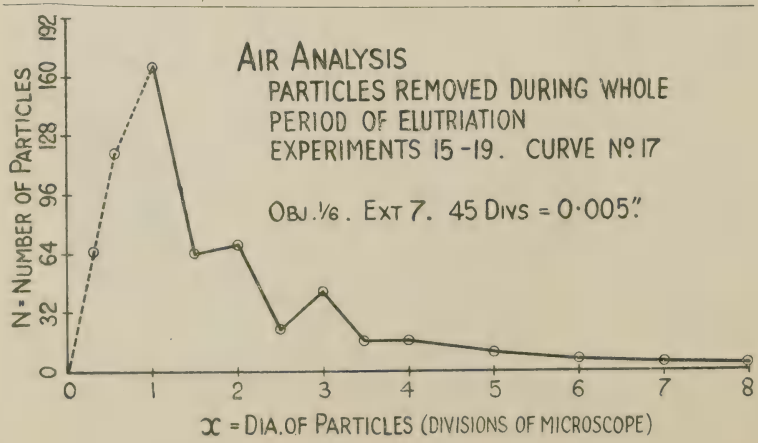


Fig. 19.

TABLE 5.

Particles removed during whole period of elutriation during experiments 15-19 inclusive.

Examined under 1/6 obj. Ext. 7. 45 divisions = 0·005″

I. Range of diam. in divs.	II. Mean of range divisions	III. Value of mean inches	IV. No. of particles measured
Below 0·25		$\times 10^{-4}$	66
0·25 – 0·75	0·5	$0{\cdot}55 \times 10^{-4}$	119
0·75 – 1·25	1·0	$1{\cdot}11 \times 10^{-4}$	167
1·25 – 1·75	1·5	$1{\cdot}67 \times 10^{-4}$	63
1·75 – 2·25	2·0	$2{\cdot}22 \times 10^{-4}$	70
2·25 – 2·75	2·5	$2{\cdot}78 \times 10^{-4}$	23
2·75 – 3·25	3·0	$3{\cdot}33 \times 10^{-4}$	44
3·25 – 3·75	3·5	$3{\cdot}89 \times 10^{-4}$	15
3·75 – 4·25	4·0	$4{\cdot}44 \times 10^{-4}$	17
4·75 – 5·5	4·5	$5{\cdot}55 \times 10^{-4}$	11
5·5 – 6·5	6·0	$6{\cdot}67 \times 10^{-4}$	6
6·5 – 7·5	7·0	$7{\cdot}78 \times 10^{-4}$	5
7·5 – 8·5	8·0	$8{\cdot}89 \times 10^{-4}$	3
			609 particles

Table 4 shows the distribution data for the particles examined by the $\frac{1}{12}$″ oil immersion lens, the results of which are plotted graphically in Figure 18. curve No. 3, whereas Table 5 shows the distribution data for the same particles examined by the $\frac{1}{6}$″

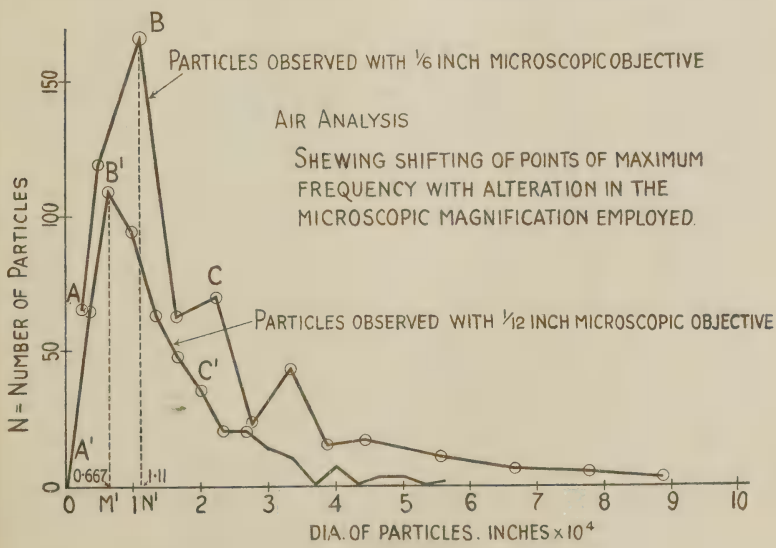


Fig. 20.

objective, the results of which are plotted graphically in Fig, 19. By comparing these two curves it will be seen that the maximum number of particles with the $\frac{1}{12}''$ oil immersion lens corresponds to those possessing a diameter of 0·0000667 inches, whereas in the case of the $\frac{1}{6}''$ objective it was 0·000111 inches.

This result comes out more clearly when both the results are plotted on the same scale, the diameters being given not as divisions of the microscope, but as *inches*. This is shown in Fig. 20. Here *ABC* is the curve of frequency when the particles are plotted as

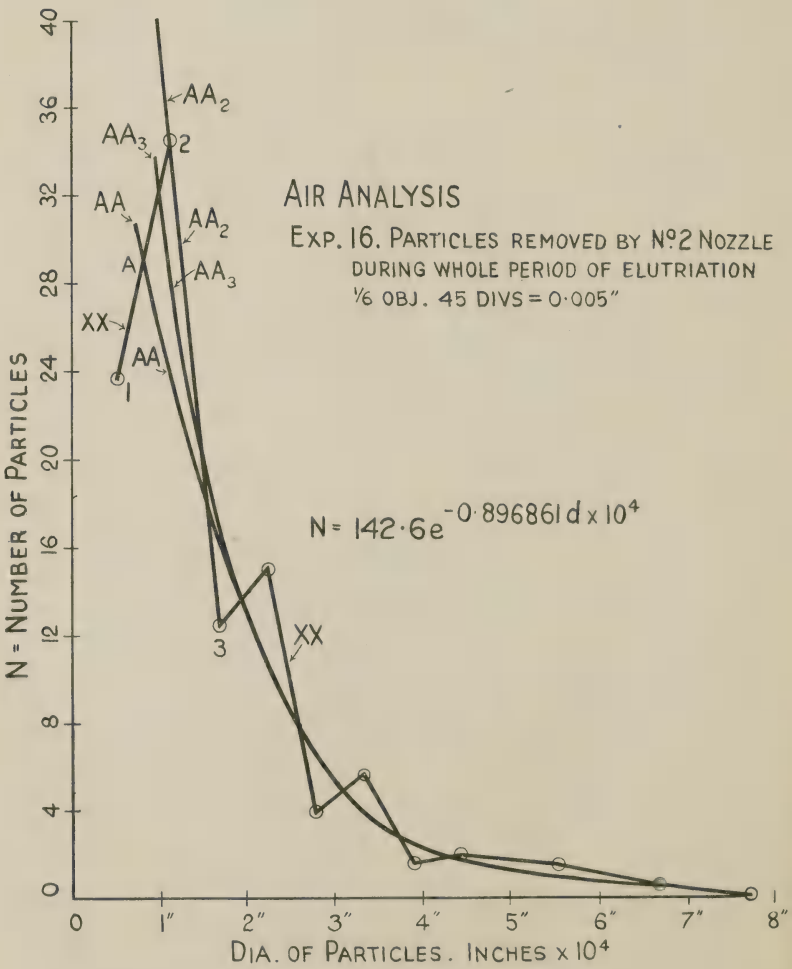


Fig. 21.

viewed under the $\frac{1}{6}''$ objective. The maximun frequency corresponds to point B and is $1{\cdot}11 \times 10^{-4}$ inch. $A^1B^1C^1$ shows the same slide viewed under the higher microscopic power of $\frac{1}{12}$ inch objective. The maximum frequency is now at B^1 corresponding to a particle size of $0{\cdot}667 \times 10^{-4}$ inch.

It is obvious, therefore, that the maximum point shifts down the scale to particles of smaller diameter as the magnifying power of the microscope is increased so that it is reasonable to suppose that, if a still higher power microscope were used, the maximum number of particles would approach even nearer the ordinate corresponding to zero diameter, and that as the diameter of the particles approaches zero (or more strictly, molecular dimensions) the number of such particles becomes a maximum.

(19). *Determination of the Form of True Frequency Curve for Diminishing Diameters of Particles.*

From these considerations it was thought that there must be some relation between x, the diameter of the particles, and N, the number of paricles of diameter x ; and that the relationship must be such that the number of particles increased according to some inverse function of the diameter.

In order to determine the true form of the frequency curve the results of experiment 16 were utilised. In this experiment No. 2 Nozzle (0·060″ diam. of aperture), was used and the pressure of the air was 40 cm. of water. The 609 particles examined represent the results of the whole period of the elutriation. The results of the experiment are set forth in Table 6.

TABLE 6.

Experiment 16. *Particles removed by No.* 2 *Nozzle.*

Comparison of data obtained from measurement of these particles removed during the whole period of the elutriation.

$\frac{1}{6}''$ objective. 45 divs. = 0·005″, or 1 div. = $1{\cdot}111 \times 10^{-4}$ inch.

I. Range of diam. in divs. of microscope	II. Mean of Range divs. of microscope	III. Value of mean Inches $\times 10^{-4}$	IV. No. of particles in range	V. Percentage No. of particles possessing diameter d
0·25 – 0·75	0·5	$0{\cdot}55 \times 10^{-4}$	144	23·644
0·75 – 1·25	1·0	$1{\cdot}11 \times 10^{-4}$	211	34·650
1·25 – 1·75	1·5	$1{\cdot}67 \times 10^{-4}$	75	12·316
1·75 – 2·25	2·0	$2{\cdot}22 \times 10^{-4}$	92	15·108
2·25 – 2·75	2·5	$2{\cdot}78 \times 10^{-4}$	23	3·776
2·75 – 3·25	3·0	$3{\cdot}33 \times 10^{-4}$	34	5·583
3·25 – 3·75	3·5	$3{\cdot}89 \times 10^{-4}$	9	1·477
3·75 – 4·25	4·0	$4{\cdot}44 \times 10^{-4}$	11	1·805
4·5 – 5·5	5·0	$5{\cdot}55 \times 10^{-4}$	8	1·313
5·5 – 6·5	6·0	$6{\cdot}67 \times 10^{-4}$	2	0 328
6·5 – 7·5	7·0	$7{\cdot}78 \times 10^{-4}$	0	0·000
			609 particles	100·000

From columns III. and V. of Table 6 we next plot the zig-zag curve *XX*, shown in Fig. 21.

From this zig-zag curve we must now draw a smoothed curve evenly between the points on the experimental curve in order to obtain mean readings. We are, however, here faced by a difficulty. We have definitely proved above that the maximum number of particles continually increases as the diameter decreases, and that the reason why the point (1) on curve *XX* indicates that the corresponding number of particles is less than those indicated by point (2) is due to the fact that particles of diameter corresponding to (1) are becoming so small as to lie beyond the range of visibility of the microscope.

Hence we know from *a priori* considerations that the ordinate of (1) is too low in value and possibly the ordinate of (2) is slightly too high in value, because it forms the next point to (3) on the zig-zag curve, (3) being admittedly too low in value as formerly explained in Section 17 above.

It is obvious, therefore, that the smoothed curve should pass intermediate between the points (1) and (2) on *XX* and lie nearer to (2) than the (1).

In order to overcome this difficulty, we proceed as follows :—

We first draw a smoothed curve *AA* cutting the line 1—2 on *XX* at the middle point *A*, and we then read off from the curve thus obtained in the column of figures shown in Column 2, Table 7. We next neglect altogether the point (1) on *XX* and draw a second smoothed curve AA_2 starting at the point (2). We now obtain, by interpolation, figures which are given in column III. In order to obtain the final smoothed curve AA_3 we take the arithmetical mean of columns (II) and (III) and thus obtain column IV.

Taking these results we plot the curve AA_3 as shown in Fig. 21.

Column 5, Table 7, shows the percentage number of particles possessing the diameter *d*, which numbers are obtained by multiplying the figures in column (4) by the factor 1·805. Column (6) represents $\text{Log}_{10}\ N$ and column (7) $\text{Log}_e\ N$.

If we now plot $\text{Log}_e\ N$ (Column 7, Table 7) against *d*, (Column 1, Table 7) and neglect the last three figures marked with an asterisk in column 7 as being unreliable (owing to an insufficient number of particles being taken in the first instance), we obtain the straight line *B.B.*, Fig. 22. The equation to which is found to be :—

$$\text{Log}_e\ N = 4{\cdot}96 - 0{\cdot}089686 \times 10^4 \times d.$$

$$\text{or } N = 142{\cdot}6_e^{-0{\cdot}89686 \times 10^4 \times d} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

It is interesting to see how closely the figures for *N* calculated for the formula (1) by giving different values to *d* compare with that found in column (5), Table 7. (1).

TABLE 7.

(1) Diameter of particles d.	(2) Number of particles of dia. d. read off from smoothed curve $A.A$.	(3) Number of particles of dia. d. read off from smoothed curve $A.A_2$.	(4) Mean of columns (2) and (3)	(5) N Percentage number of particles possessing diameter d. obtained from column 4	(6) $\text{Log}_{10}\ N$.	(7) $\text{Log}_e\ N. = \text{Log}_{10}\ N. \times 2{\cdot}3026$
1×10^{-4}	25·9	39·2	32·55	58·751	1·7680153	4·071
2×10^{-4}	12·9	13·0	12·95	23·377	1·3687888	3·1515
3×10^{-4}	5·4	5·4	5·4	9·750	0·9890046	2·2773
4×10^{-4}	2·2	2·2	2·2	3·971	0·5988999	1·3790
5×10^{-4}	1·2	1·2	1·2	2·166	0·3356585	0·77283*
6×10^{-4}	0·8	0·8	0·8	1·444	0·1595672	0·3674*
7×10^{-4}	0·3	0·3	0·3	0·541	0·2668027	0·61430*
	48·7	62·1	55·40	100·000		

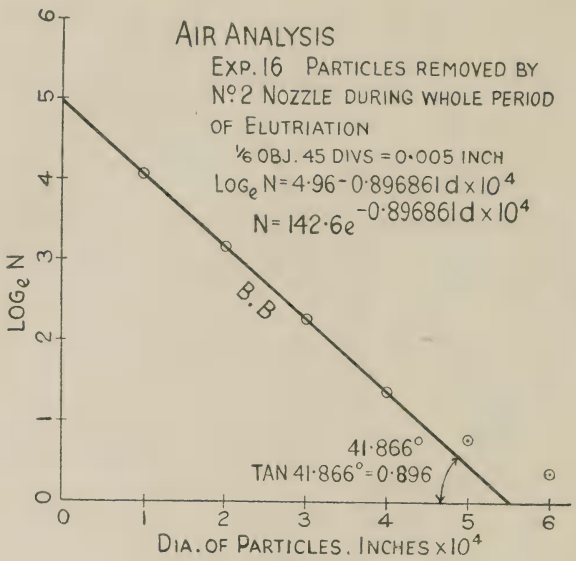


Fig. 22.

TABLE 8.

d.	Experimental value of N. from smoothed curve	Value of N. calculated from formula	Ratio of successive ordinates N_2/N_1
1×10^{-4}	58·751	58·17	
2×10^{-4}	23·377	23·72	2·45
3×10^{-4}	9·750	9·66	2·45
4×10^{-4}	3·971	3·945	2·45
5×10^{-4}	2·166*	1·600*	2·46
6×10^{-4}	1·444*	0·655*	2·44
7×10^{-4}	0·541*	0·267*	2·45

It will be noticed that the calculated and experimentally obtained results agree very closely except when we get into values of d corresponding to particles of such a size that too few were counted for accuracy, according to the ordinary law of probability (marked with an asterisk).

(20). *Repetition of Previous Results using $\frac{1}{12}''$ Objective instead of $\frac{1}{6}''$ Objective.*

The previous results refer to the measurement of the particles of experiment 16, when they were examined by a $\frac{1}{6}''$ objective (45 divs. = 0·005 inches).

The same number of particles obtained from the same experiment were now examined under a $\frac{1}{12}''$ objective (oil immersion lens).

The results are shown in the following table.

TABLE 9.

Particles removed during expt. 16 whole period of elutriation measured by $\frac{1}{12}''$ oil immersion lens Ext. 7. 30 divs. = 0·001″. 1 div. = $0{\cdot}333 \times 10^{-4}$ inches.

I. Range of diameter in divs.	II. Mean of range in divs.	III. Value of mean in inches d.	IV. No. of particles in range	V. Percentage No. of particles possessing diam. d.
0·5 – 1·5	1	$0{\cdot}333 \times 10^{-4}$	80	13·136
1·5 – 2·5	2	$0{\cdot}667 \times 10^{-4}$	136	22·333
2·5 – 3·5	3	$1{\cdot}000 \times 10^{-4}$	112	18·392
3·5 – 4·5	4	$1{\cdot}33 \times 10^{-4}$	77	12·644
4·5 – 5·5	5	$1{\cdot}67 \times 10^{-4}$	59	9·688
5·5 – 6·5	6	$2{\cdot}00 \times 10^{-4}$	44	7·225
6·5 – 7·5	7	$2{\cdot}33 \times 10^{-4}$	26	4·269
7·5 – 8·5	8	$2{\cdot}67 \times 10^{-4}$	26	4·269
8·5 – 9·5	9	$3{\cdot}00 \times 10^{-4}$	17	2·791
9·5 – 10·5	10	$3{\cdot}33 \times 10^{-4}$	13	2·135
10·5 – 11·5	11	$3{\cdot}67 \times 10^{-4}$	0	0·000
11·5 – 12·5	12	$4{\cdot}00 \times 10^{-4}$	9	1·478
12·5 – 13·5	13	$4{\cdot}33 \times 10^{-4}$	4	0·656
13·5 – 14·5	14	$4{\cdot}67 \times 10^{-4}$	4	0·656
14·5 – 15·5	15	$5{\cdot}00 \times 10^{-4}$	2	0·328
			609	100·000

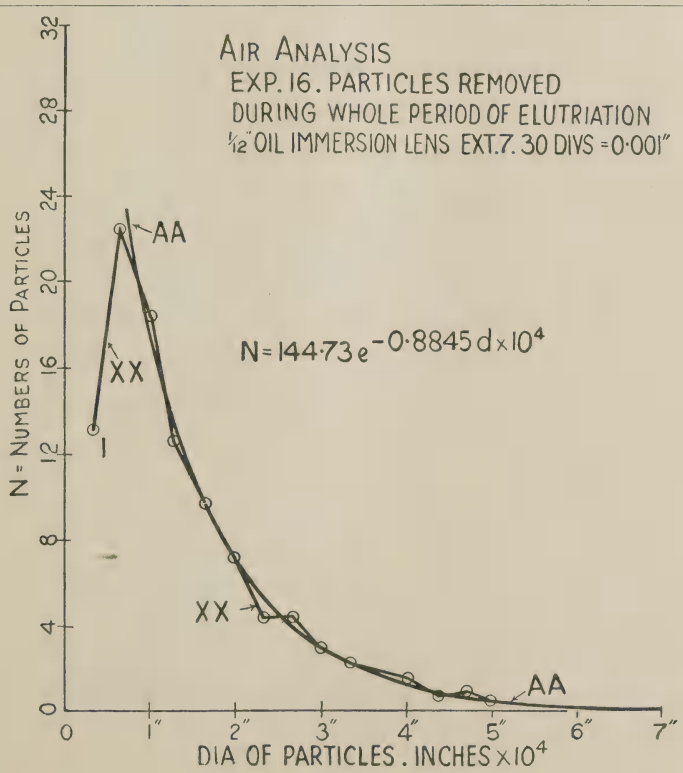


Fig. 23.

By plotting Columns III. and V. from Table 9 we obtain the experimental zig-zag curve XX shown in Fig. 23, and from this curve we draw the smoothed curve AA evenly between the points on the experimental curve.

The point (1) on this curve is neglected because it is obviously incorrect owing to the diminution in visibility of the particles under the microscope when their sizes become smaller than $0{\cdot}5 \times 10^{-4}$ inches.

From the smoothed curve AA we next read off the following mean diameters shown in column (2) of Table 10; Column (3) gives the percentage Number N, Col. (4) gives $\text{Log}_{10} N$, Col. (5) gives $\text{Log}_e N$.

TABLE 10.

1. Diameter of particles in inches d.	2. Number of particles possessing diam. d. read from smoothed curve	3. N. Percentage No. of particles diam. d. calculated from 2	4. $\text{Log}_{10} N$.	5. $\text{Log}_e N$. $= \text{Log}_{10} N \times 2{\cdot}3026$
1×10^{-4}	17·50	60·050	1·7786	4·095
2×10^{-4}	7·10	24·367	1·3867	3·193
3×10^{-4}	2·96	10·158	1·0068	2·318
4×10^{-4}	1·22	4·187	0·6219	1·432
5×10^{-4}	0·33	1·133	0·0542	0·125
6×10^{-4}	0·03	0·103	− 0·9872	− 2·273
7×10^{-4}	0·0005	0·002	− 2·6990	− 6·214
	29·14	100·000		

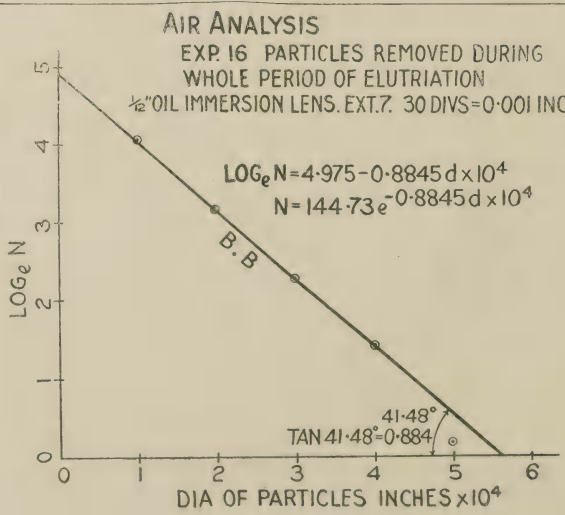


Fig. 24.

We now plot $\text{Log}_e N$ (Col. V., Table 10) against d (Col. I., Table 10) and obtain the straight line shown in Fig. 24. In drawing the latter curve only the last four points are considered, as the other numbers are too small to be reliable. The equation of the straight line B.B. is found to be :—

$$\text{Log}_e N = 4{\cdot}975 - 0{\cdot}8845 \times 10^4 \times d.$$

$$\text{or } N = 144{\cdot}73e^{-0{\cdot}8845 \times 10^4 \times d} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

(21). *Comparison of Results from the Smoothed Curve and those fitting a True Compound Interest Curve.*

It is interesting to see how closely the values of N corresponding to a given value of d, as calculated from this formula, agree with those actually found from the experimental smoothed curve AA (Fig. 23).

The numbers N as calculated from the formula are those which would be obeyed if the frequencies strictly followed the compound interest law.

The numbers as read off from the smoothed curve may be regarded as the numbers found by experiment.

Table 11 shows the result of this comparison :—

TABLE 11.

I. d.	II. Experimental value of N. read from smoothed curve AA (Fig. 23).	III. Value of N. calculated from formula 2.	IV. Ratio of successive ordinates N_2/N_1 of col. III.
1×10^{-4}	60·05	59·76	
2×10^{-4}	24·367	24·68	2·422
3×10^{-4}	10·158	10·19	2·422
4×10^{-4}	4·187	4·20	2·426
5×10^{-4}	1·133	1·73	2·428
6×10^{-4}	0·103	*0·717	2·41
7×10^{-4}	0·002	*0·296	2·42

It will be seen that the agreement is extraordinarily close.

(22). *Nearly identical Frequency Curves are obtained by using Different Magnifications in the Microscopic Objective.*

On comparing the frequency curves obtained by using $\frac{1}{12}''$ oil immersion objective with those obtained by using the $\frac{1}{6}$th, it will be seen that they very closely correspond to each other and that the values may be calculated extremely closely by the logarithmic formulæ previously developed, showing that in each case the compound interest law is followed. The following table makes this clear :—

TABLE 12.

I. Diameter of particles d. inches	II. Percentage found using $\frac{1}{6}$th. obj.	III. No. of particles Calcd. by logarithmic formula $\frac{1}{6}$th. obj.	IV. Found using $\frac{1}{12}$th objective	V. Calcd. by logarithmic formula using $\frac{1}{12}$th. inch obj.
1×10^{-4}	58·751	58·170	60·050	59·760
2×10^{-4}	23·377	23·720	24·367	24·680
3×10^{-4}	9·750	9·660	10·158	10·190
4×10^{-4}	3·971	3·945	4·187	4·200
5×10^{-4}	2·166	1·600	1·133	1·730
6×10^{-4}	1·444	0·655	0·103	0·717
7×10^{-4}	0·541	0·267	0·002	0·296

(23). *Frequency Curves for Particles blown off from the Ground Sand during the first* 15 *minutes of Air Elutriation lasting two hours.*

In experiments (25) and (26) 33·3 grams of ground sand (ground in the 18″ mill, experiment II. of 1920, 3·68 per cent. residue on 180^2 cement sieve) were elutriated for two hours, and samples of the particles removed were collected during the first 15 minutes and the last 15 minutes of the experiment, and also over the whole period of the experiment. Table 13 shows the results of a slide made with the particles removed during the first 15 minutes as examined by the $\frac{1}{6}$th objective.

TABLE 13.

Exp. No. 25. Particles removed during first 15 mins.
Examined by 1/6″, obj. Ext. 7. 45 divs. = 0.005″.

I. Range of diameters in divs.	II. Mean of range in divs.	III. Value in inches	IV. No. of particles in range	V. Percentage No. of particles possessing diameter d.
0·25 – 0·75	0·5	$0{\cdot}55 \times 10^{-4}$	169	27·748
0·75 – 1·25	1·0	$1{\cdot}11 \times 10^{-4}$	232	38·093
1·25 – 1·75	1·5	$1{\cdot}67 \times 10^{-4}$	68	11·169
1·75 – 2·25	2·0	$2{\cdot}22 \times 10^{-4}$	66	10·839
2·25 – 2·75	2·5	$2{\cdot}78 \times 10^{-4}$	23	3·777
2·75 – 3·25	3·0	$3{\cdot}33 \times 10^{-4}$	25	4·105
3·25 – 3·75	3·5	$3{\cdot}89 \times 10^{-4}$	10	1·642
3·75 – 4·25	4·0	$4{\cdot}44 \times 10^{-4}$	11	1·806
4·5 – 5·5	5·0	$5{\cdot}55 \times 10^{-4}$	3	0·493
5·5 – 6·5	6·0	$6{\cdot}67 \times 10^{-4}$	0	0·000
6·5 – 7·5	7·0	$7{\cdot}78 \times 10^{-4}$	2	0·328
			609 particles	100·00

By plotting Column III. against Column V. from Table 13, the zig-zag experimental curve XX, (Fig. 25), was constructed. Following the previous table constructed, a smoothed curve A.A is now drawn between the points, as shown. We then, from this curve, read off the ordinates and thus obtain the following table 14.

TABLE 14.

I. d. diameter of particle in inches	II No. of particles of diam. d read off from smoothed curve AA.	III. Percentage No. of particles possessing diam. d. calculated from Col. 2. N.	IV. $\text{Log}_{10} N$.	V. $\text{Log}_e N$. $= \text{Log}_{10} N$. $\times 2{\cdot}3026$
1×10^{-4}	34·5	65·63	1·8171	4·184
2×10^{-4}	10·2	19·42	1·2882	2·966
3×10^{-4}	4·3	8·18	0·9128	2·10169
4×10^{-4}	1·98	3·77	0·5763	1·3271
5×10^{-4}	0·97	1·84	0·2648	0·6098
6×10^{-4}	0·43	0·82	–0·0862	– 0·198
7×10^{-4}	0·18	0·34	–0·4685	– 1·079
	52·56	100·00		

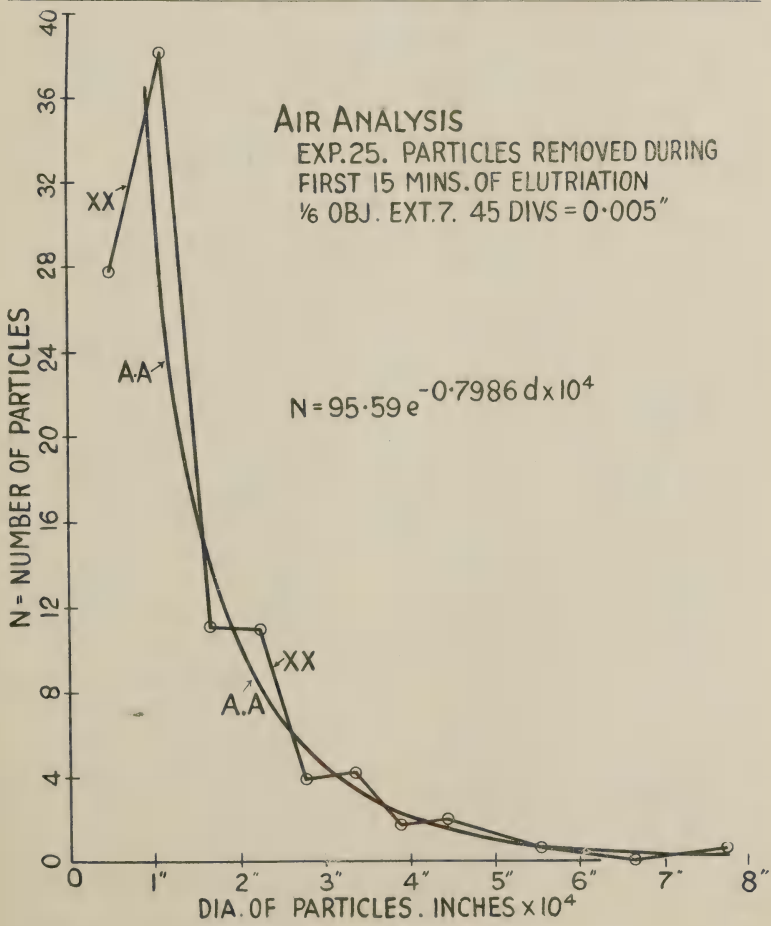


Fig. 25.

Column III shows the percentage number of particles possessing diameter d, which numbers were obtained by multiplying the figures in column (II) by the factor 1·9026.

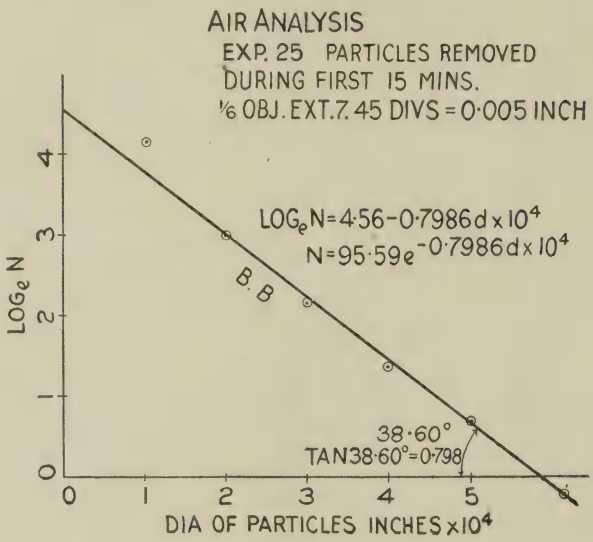


Fig. 26.

Column IV gives $\text{Log}_{10} N$, and column 5 gives $\text{Log}_e N$. We now plot $\text{Log}_e N$ (Col. V) against (d), and obtain the straight line B.B. (Fig. 26), showing that the logarithmic law is still obeyed. The equation of the curve is found to be :—

$$N = 95{\cdot}59e^{-0{\cdot}7986d \times 10^4} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (X).$$

Substituting different values of d from $d = 1 \times 10^{-4}$ to $d = 7 \times 10^{-4}$ in equation (X) we obtain the following table :—

TABLE 15.

I. Mean diameter d.	II. Experimentally found value of N from smoothed curve AA (Fig. 25).	III. Calculated value of N from formula (X).	IV. Ratio of successive ordinates N_2/N_1. of Col. III.
1×10^{-4}	65·63	43·01	
2×10^{-4}	19·42	19·35	2·223
3×10^{-4}	8·18	8·70	2·224
4×10^{-4}	3·77	3·92	2·220
5×10^{-4}	1·84	1·76	2·227
6×10^{-4}	0·82	0·79	2·228
7×10^{-4}	0·34	0·357	2·212
	100·00	77·68	

It will be noticed that, except for the first result for very small particles, the correspondence to the theoretical result is very close.

It appears, however, that in this sample the particles corresponding to the smallest diameter are more numerous than they should be according to the law.

(24). *Frequency Curves for Particles blown off from the Ground Sand during the last* 15 *minutes of an Air Elutriation lasting two hours.*

The foregoing results of (23) related to particles removed during the first 15 minutes of the air blowing. It was interesting to compare the results obtained with particles removed during the last 15 minutes. The results are shown in Table 16.

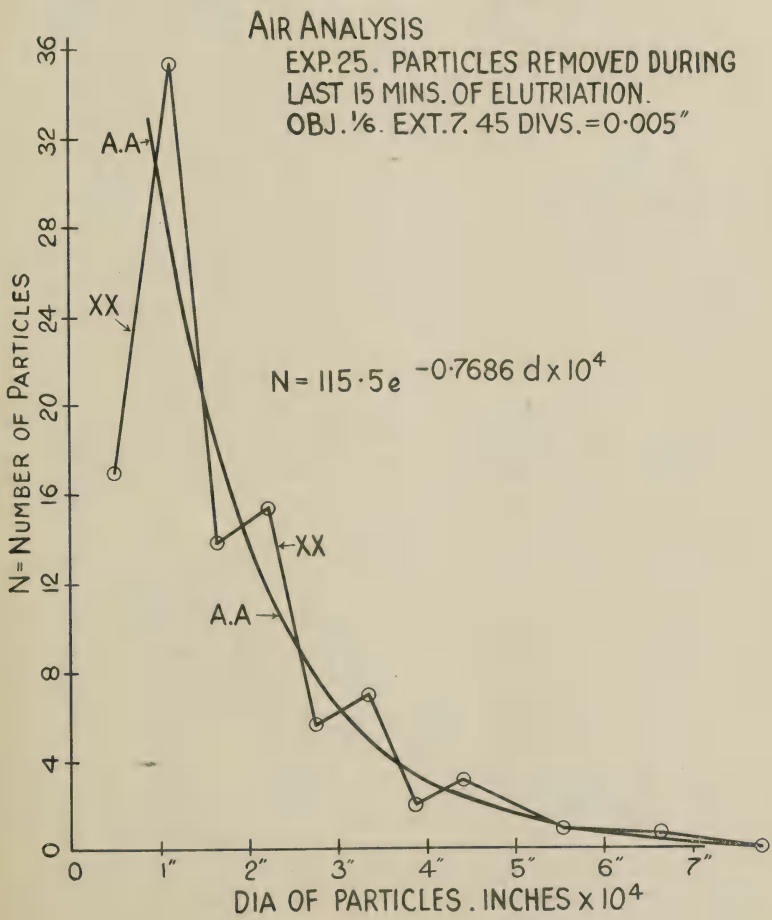


Fig. 27

TABLE 16.

Expt. 25. Particles removed during last 15 mins. of experiment.
Obj. $\frac{1}{6}''$. Ext. 7. 45 divs. = 0·005″.

I. Range of dia. in divisions	II. Mean of range in divisions	III. Value in inches	IV. No. of particles in range	V. Percentage No. of particles possessing diameter d.
0·25 – 0·75	0·5	$0{\cdot}55'' \times 10^{-4}$	103	16·912
0·75 – 1·25	1·0	$1{\cdot}11 \times 10^{-4}$	215	35·304
1·25 – 1·75	1·5	$1{\cdot}67 \times 10^{-4}$	85	13·958
1·75 – 2·25	2·0	$2{\cdot}22 \times 10^{-4}$	93	15·270
2·25 – 2·75	2·5	$2{\cdot}78 \times 10^{-4}$	34	5·583
2·75 – 3·25	3·0	$3{\cdot}33 \times 10^{-4}$	42	6·897
3·25 – 3·75	3·5	$3{\cdot}89 \times 10^{-4}$	12	1·971
3·75 – 4·25	4·0	$4{\cdot}44 \times 10^{-4}$	18	2·956
4·5 – 5·5	5·0	$5{\cdot}55 \times 10^{-4}$	5	0·821
5·5 – 6·5	6·0	$6{\cdot}67 \times 10^{-4}$	2	0·328
6·5 – 7·5	7·0	$7{\cdot}78 \times 10^{-4}$	0	0·000
			609 particles	100·000

From Columns III. and V. of Table 16 we construct the zig-zag curve XX. (Fig. 27) is plotted and the smooth curve AA is constructed. From the smooth curve the ordinates are read off and we then obtain the following table 17.

TABLE 17.

I. Mean diam. of particles in inches d.	II. No. of particles of diam. d read off from smooth curve.	III. Percentage No. of particles possessing dia. d. calcd. from (2). N.	IV. $\text{Log}_{10}N$.	V. $\text{Log}_e N$. $= \text{Log}_{10}N. \times 2{\cdot}3026$
1×10^{-4}	30·4	54·152	1·7336145	3·9918
2×10^{-4}	14·0	24·944	1·3969661	3·2165
3×10^{-4}	6·4	11·408	1·0572095	2·4343
4×10^{-4}	2·88	5·130	0·7101174	1·6351
5×10^{-4}	1·48	2·637	0·4211101	0·9696
6×10^{-4}	0·72	1·283	0·1082267	0·2492
7×10^{-4}	0·25	0·446	–0·3506651	–0·8074
	56·13	100·000		

We now plot $\text{Log}_e N$ against $d \times 10^4$ as before and obtain the straight line B.B. (Fig. 28).

The equation of this curve is :—$\text{Log}_e N = 4{\cdot}75 - \dfrac{4{\cdot}75\, d \times 10^4}{6{\cdot}18}$

$= 4{\cdot}75 - 0{\cdot}7686\, d \times 10^4$

Whence $N = 155{\cdot}5e^{-0{\cdot}7686\, d \times 10^4}$

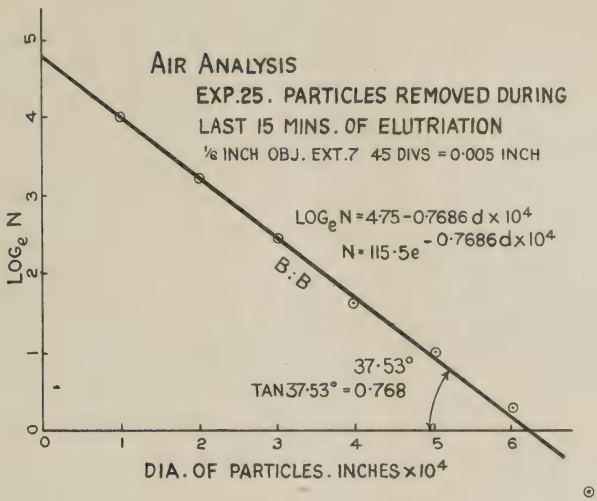


Fig. 28.

From this equation we obtain the following Table 18.

TABLE 18.

d. mean diam. of particles. inches.	Experimental value of N. Read from smoothed curve.	Calculated values of N from formula.	Ratio of successive ordinates. N_2/N_1.
1×10^{-4}	54·152	53·592	
2×10^{-4}	24·944	24·849	2·157
3×10^{-4}	11·408	11·522	2·157
4×10^{-4}	5·130	5·342	2·157
5×10^{-4}	2·637	2·474	2·15
6×10^{-4}	1·283	1·1485	2·15
7×10^{-4}	0·446	+ 0·5325	2·157
	100·000		

On comparing the calculated with the experimental figures, it will be seen again that the compound interest law is obeyed extremely closely in this case also.

(25). *Frequency Curves for Particles blown off from the Ground Sand during the Whole Two Hours of Blowing.*

We now compare the results with those obtained from particles obtained over the whole period of blowing. The experimental results obtained are set forth in Table 19.

From Columns III. and V. of Table 19 we construct the zig-zag curve XX, (Fig. 29) and the smooth curve A.A. is constructed, as before described. From the smooth curve the ordinates are read off as before and we then obtain the following table 20.

TABLE 19.

Data of actual experimental distribution curve. (Points joined by straight lines).

Exps. 25-26. Particles removed during whole period of elutriation examined by $\frac{1}{6}''$ obj. Ext. 7. 45 divs. = 0·005″.

I. Range of dia. divs.	II. Mean of range divs.	III. Mean of range. inches. d	IV. No. of Particles in range.	V. Percentage No. of particles possessing d diameter. N.
Below 0·25			108	17·7340
0·25 – 0·75	0·5	$\cdot 55'' \times 10^{-4}$	102	16·7490
0·75 – 1·25	1·0	$1\cdot 11 \times 10^{-4}$	160	26·2730
1·25 – 1·75	1·5	$1\cdot 67 \times 10^{-4}$	60	9·8520
1·75 – 2·25	2·0	$2\cdot 22 \times 10^{-4}$	69	11·3300
2·25 – 2·75	2·5	$2\cdot 78 \times 10^{-4}$	19	3·1198
2·75 – 3·25	3·0	$3\cdot 33 \times 10^{-4}$	37	6·0754
3·25 – 3·75	3·5	$3\cdot 89 \times 10^{-4}$	14	2·2987
3·75 – 4·25	4·0	$4\cdot 44 \times 10^{-4}$	16	2·6273
4·25 – 4·75	4·5	$5\cdot 00 \times 10^{-4}$	6	0·9852
4·75 – 5·25	5·0	$5\cdot 55 \times 10^{-4}$	8	1·3136
5·25 – 5·75	5·5	$6\cdot 11 \times 10^{-4}$	2	0·3284
5·75 – 6·25	6·0	$6\cdot 67 \times 10^{-4}$	6	0·9852
6·5 – 7·5	7·0	$7\cdot 78 \times 10^{-4}$	2	0·3284
			609	100·0000

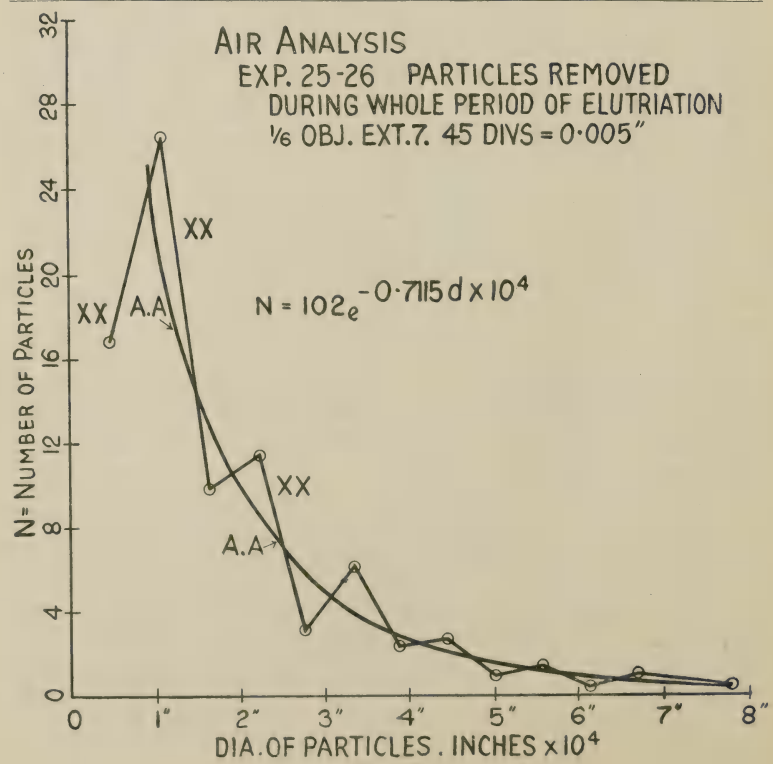


Fig. 29.

TABLE 20.

I. d. Dia. of particles in inches. d.	II. No. of Particles of d. dia. read off smooth curve.	III. N. Percentage No. of particles possessing dia. d. calcd. from (2).	IV. $\text{Log}_{10} N$.	V. $\text{Log}_e N$.
1×10^{-4}	23·2	53·430	1·7277852	3·9784
2×10^{-4}	10·0	23·031	1·3623128	3·1368
3×10^{-4}	4·9	11·285	1·0525016	2·4235
4×10^{-4}	2·65	6·104	0·7856145	1·8090
5×10^{-4}	1·38	3·179	0·5022905	1·1566
6×10^{-4}	0·77	1·773	0·2487087	0·5726
7×10^{-4}	0·52	1·198	0·0784568	0·1806
	43·42	100·000		

We now plot $\text{Log}_e N$ against $d \times 10^4$ as before and obtain the straight line BB. (Fig. 30.)

The equation of this straight line is $\text{Log}_e N = 4{\cdot}625 - 0{\cdot}7115\ d \times 10^4$, whence $N = 102{\cdot}0\ e^{-0{\cdot}7115 d \times 10^4}$. Substituting different values of d we obtain the following table 21.

TABLE 21.

I. Mean diameter of particles d.	II. Experimental value of N from smoothed curve.	III. Calculated value of N from formula.	IV. Ratio of successive ordinates. N_2/N_1 from col. III.
1×10^{-4}	53·430	50·073	
2×10^{-4}	23·031	24·582	2·037
3×10^{-4}	11·285	12·067	2·037
4×10^{-4}	6·104	5·9180	2·038
5×10^{-4}	3·179	2·9081	2·035
6×10^{-4}	1·773	1·4275	2·037
7×10^{-4}	1·198	0·70083	2·037

Again it will be seen that the correspondence is extremely close, so that the compound interest law is obeyed by the particles in this case as well.

(26). *Summary of Results as regards Air Elutriated Particles.*

All the preceding results were obtained with particles removed from crushed sand by air elutriation. In every case treated the frequency curve connecting the number of particles with the diameter does *not* follow the ordinary *probable error curve,* but follows a curve corresponding to the *compound interest law*

(27). *Frequency Curves of Sand Particles taken directly from the Tube Mill.*

Attention was next directed to the law of particle size in the sand as crushed in the tube mill without being subjected to a subsequent air elutriation process. The following experiments show that in this case also the same compound interest law prevailed.

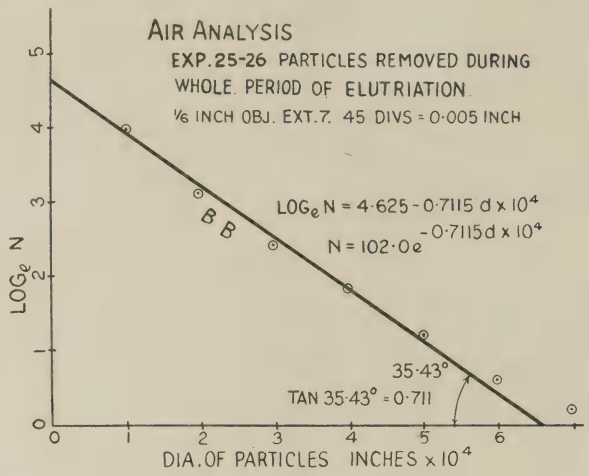


Fig. 30.

In these later experiments, however, the microscopic measurements of the diameters were carried out in a slightly different manner to those obtained in the preceding results, so as to avoid entering the region near the limits of microscopic visibility, which occasioned so much trouble in the preceding work. Also a larger number of particles were measured in each case so as to reduce the irregularity of the results and approximate to a more continuous curve.

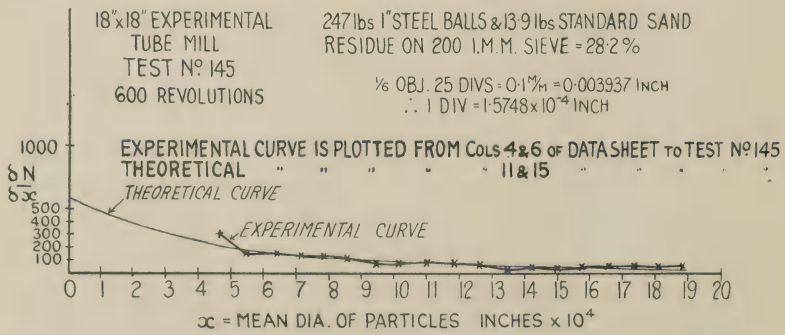


Fig. 31.

The psychological factors were thus largely eliminated and only appear in the first and last of a series of tabulated values—owing to an unconscious effort made by the microscopic observers of gathering too many particles into the fold in the first effort, and of relaxing their effort towards the final values.

The results obtained, however, are remarkably concordant even when obtained by several different workers, and can leave no doubt as regards the essential validity of the compound interest law in this region of fine grinding.

All the *microscopic observations* in the following tests 145 to 153 were made under identical conditions, which were, briefly, as follows: The sample of crushed sand to be examined was lightly sifted on to a microscopic slide so as to distribute the particles over it as evenly as possible. This slide was then examined under the microscope, using the $\frac{1}{6}$ inch objective; 25 divisions on the microscopic scale were made equal to 0·1 mm. Any particle whose diameter was less than 2·75 divisions ($4{\cdot}331 \times 10^{-4}$ ins.) and larger than 12·25 divisions was rejected. Any particle whose diameter was between 2·75 and 3·25 divisions ($4{\cdot}731 \times 10^{-4}$ and $5{\cdot}118 \times 10^{-4}$ ins.) was considered as possessing the mean diameter of 3 divisions or $4{\cdot}724 \times 10^{-4}$ inches. A similar procedure was adopted with all particles whose diameters ranged between the limits of 2·75 and 12·25 divisions. The tests were carried out as follows:—The standard (nearly white Leighton Buzzard) sand was dried, and graded by passing through a 20-meshes-per-inch cement sieve and retaining on a 30-meshes-per-inch cement sieve. The average diameter of the particles was 0·02748.″ Next 13·9 lbs. of this sand were placed with 247 lbs. of 1 inch steel balls in the experimental 18″ × 18″ tube mill, and the latter allowed to rotate for 600 revolutions. The mill was then stopped, the sand withdrawn, and a small sample was sifted on the microscopic slide and examined as above described. The results are shown on the data sheet to test 145. Next a fresh batch of sand of equal weight was placed in the mill and the latter allowed to revolve for 1,200 revolutions, when again the sand was withdrawn and examined under the microscope. The results are shown on the data sheet to test 146. The same procedure was adopted for 1,800, 2,400, 3,000. 4,000, 5,000, 7,500, and 10,000 revolutions and the results entered upon data sheets to tests 147, 148, 149, 150, 151, 152 and 153 as shown below.

(28). *Method of working out the Results.*

In this new series of observations the number of particles δN observed over a small range of diameter δX ($=0{\cdot}5$ of a microscopic division $=0{\cdot}7874 \times 10^{-4}$ inch) was noted (col. 5 in data sheets) and the ratio $\frac{\delta N}{\delta X}$ calculated by dividing δN by 0·7874, and the result set forth in col. 6. of the data sheets.

We thus obtain the rate of increase in the number of particles per unit increase in the value of the diameter for each instantaneous value of the diameter X, presented by the sample of sand observed under the microscope.

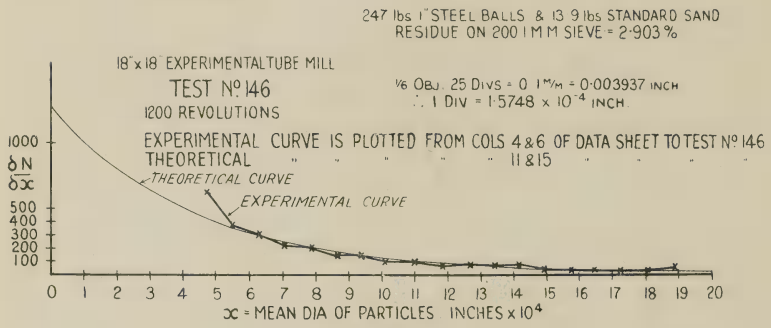


Fig. 32.

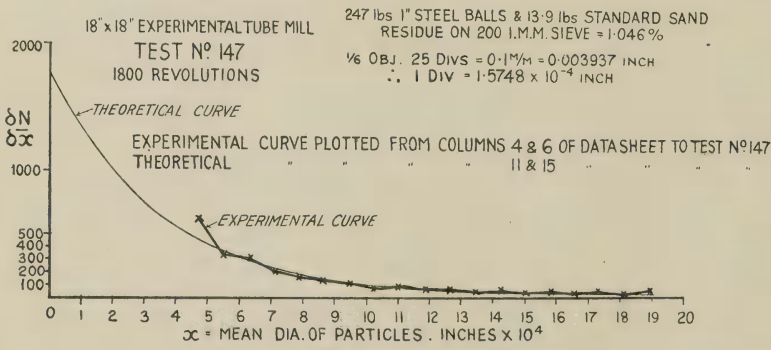


Fig. 33.

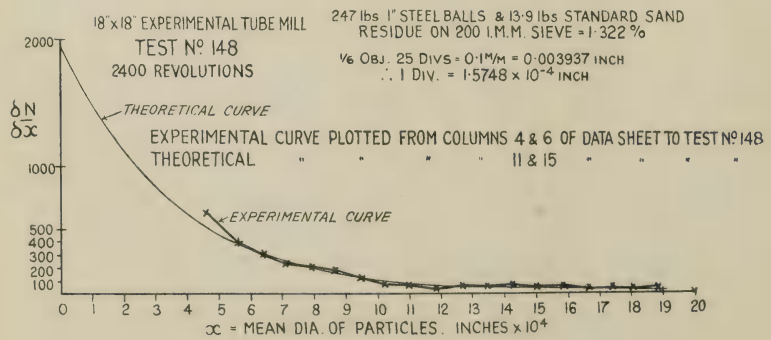


Fig. 34.

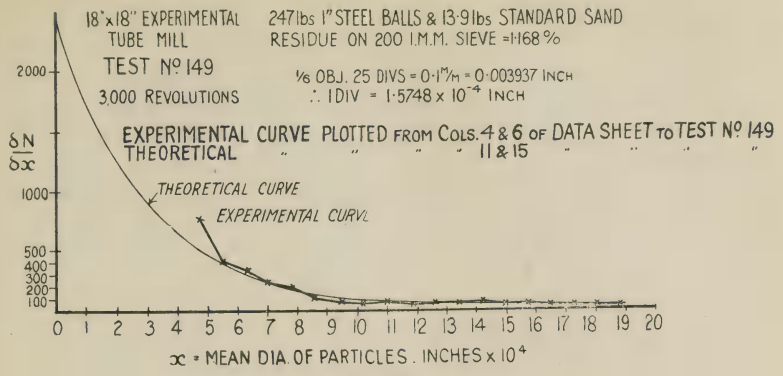


Fig. 35.

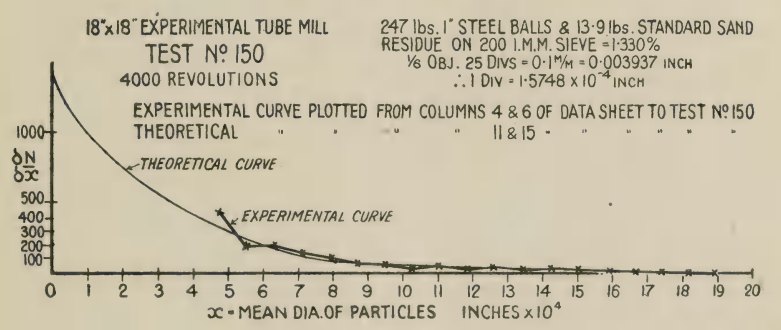


Fig. 36.

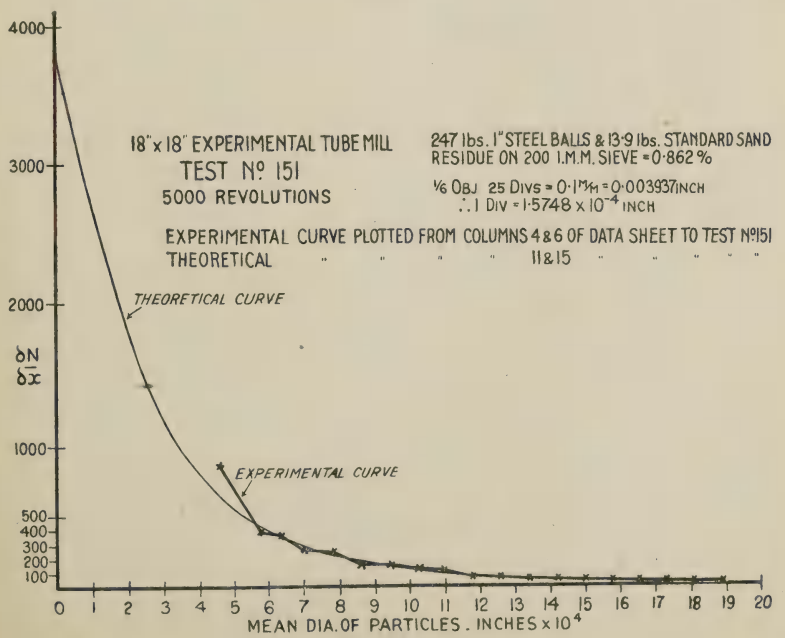


Fig. 37.

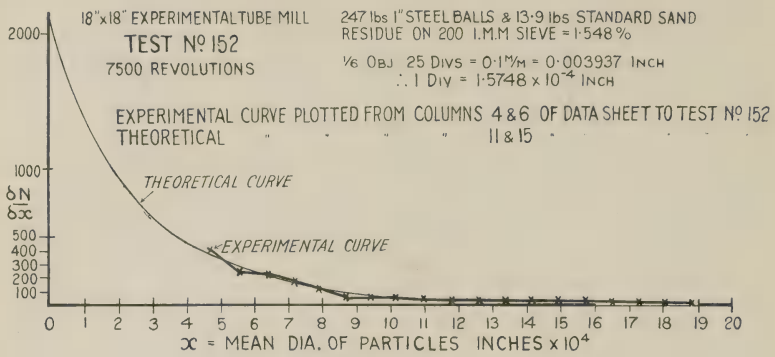

18"x18" EXPERIMENTAL TUBE MILL
TEST Nº 152
7500 REVOLUTIONS
247 lbs 1" STEEL BALLS & 13·9 lbs STANDARD SAND
RESIDUE ON 200 I.M.M SIEVE = 1·548 %
1/6 OBJ 25 DIVS = 0·1 M/M = 0·003937 INCH
∴ 1 DIV = 1·5748 x 10⁻⁴ INCH
EXPERIMENTAL CURVE PLOTTED FROM COLUMNS 4 & 6 OF DATA SHEET TO TEST Nº 152
THEORETICAL " " " " 11 & 15 "
THEORETICAL CURVE
EXPERIMENTAL CURVE
δN/δx
x = MEAN DIA. OF PARTICLES INCHES x 10⁴

Fig. 38.

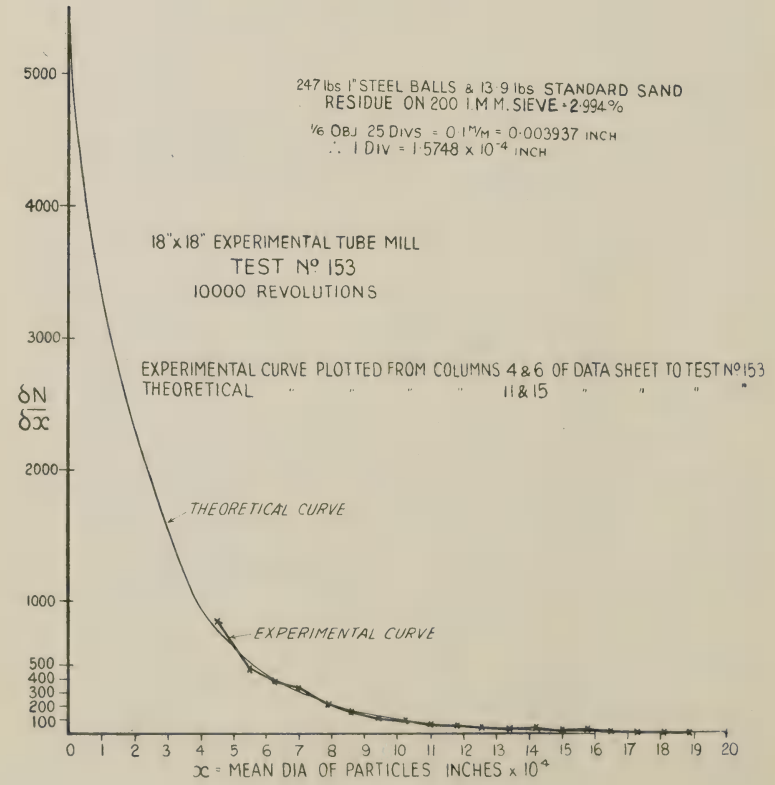

247 lbs 1" STEEL BALLS & 13·9 lbs STANDARD SAND
RESIDUE ON 200 I.M.M. SIEVE = 2·994 %
1/6 OBJ 25 DIVS = 0·1 M/M = 0·003937 INCH
∴ 1 DIV = 1·5748 x 10⁻⁴ INCH
18"x18" EXPERIMENTAL TUBE MILL
TEST Nº 153
10000 REVOLUTIONS
EXPERIMENTAL CURVE PLOTTED FROM COLUMNS 4 & 6 OF DATA SHEET TO TEST Nº 153
THEORETICAL " " " " 11 & 15 " " " "
δN/δx
THEORETICAL CURVE
EXPERIMENTAL CURVE
x = MEAN DIA OF PARTICLES INCHES x 10⁴

Fig. 39.

These experimental values of $\frac{\delta N}{\delta X}$ (col. 6.) were then plotted against the corresponding values of the diameters X expressed in inches $\times 10^{-4}$ (col. 4) and an experimental zig-zag frequency curve was obtained as set forth in Figs. 31 to 39.

Next the natural logarithms of $\frac{\delta N}{\delta X}$ (col. 8 of data sheets) were plotted against the same diameters X and in each case a *straight line* AB was obtained as shown in Figs. 40 to 48.

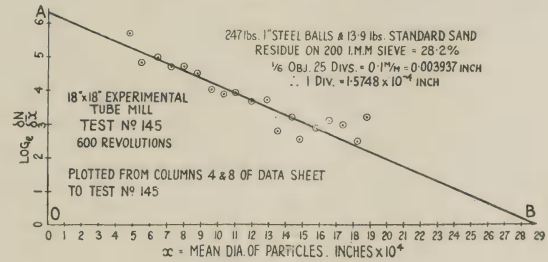


Fig. 40.

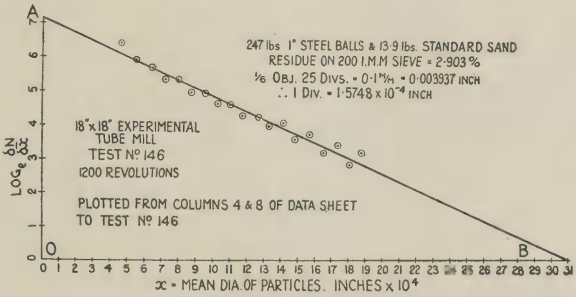


Fig. 41.

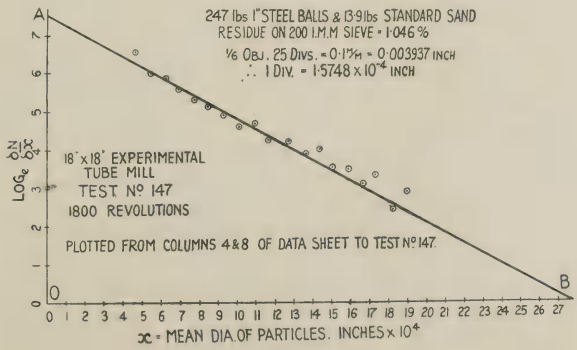


Fig. 42.

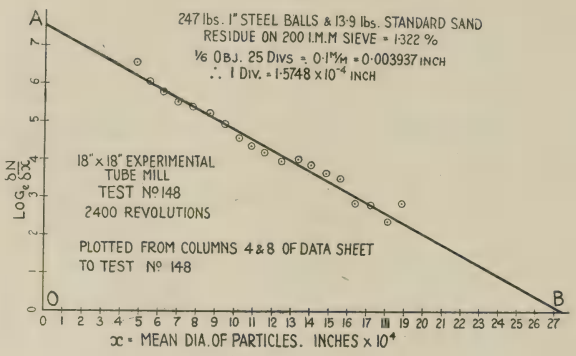


Fig. 43.

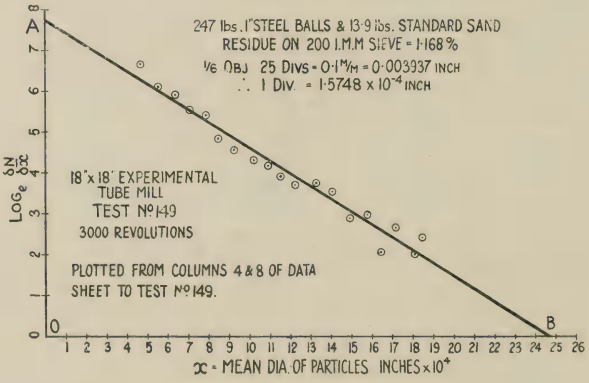


Fig. 44.

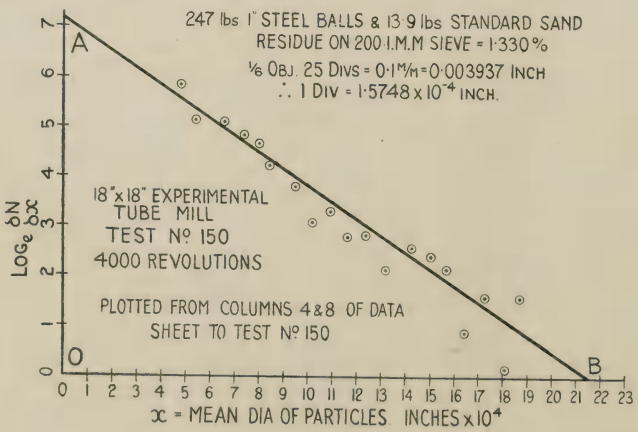


Fig. 45.

From this logarithmic straight line AB the smoothed curve was constructed by reading off the logarithms of $\frac{\delta N}{\delta X}$ corresponding to successive diameters X, and then determining the numbers corresponding to $\frac{\delta N.}{\delta X}$

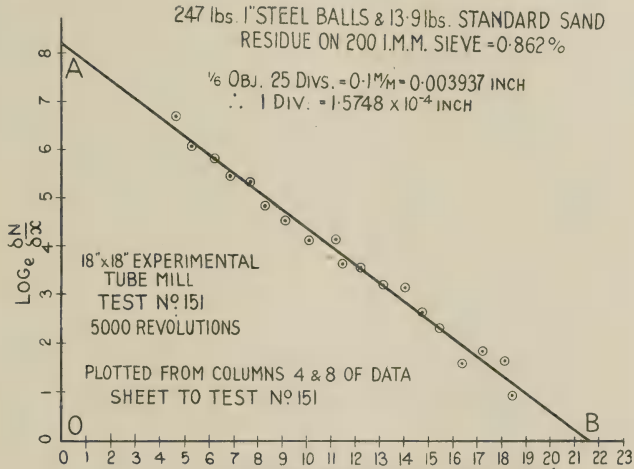


Fig. 46.

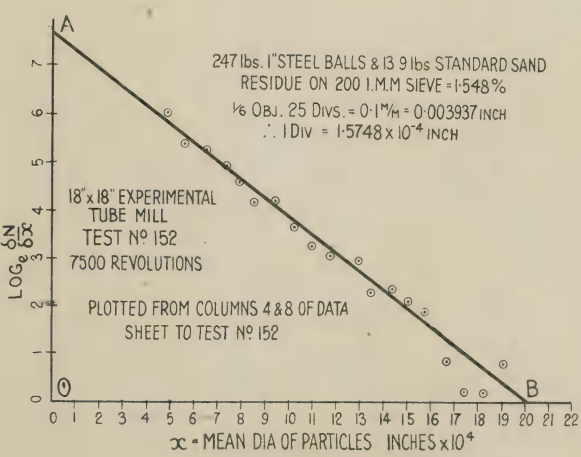


Fig. 47.

The results were counterchecked by evaluating the constants a and b from the straight line AB (col. 9 and 10 of data sheets), and calculating therefrom the theoretical values of $\frac{\delta N}{\delta X}$ as shown in columns 11, 12, 13, 14 and 15 of the data sheets.

From the results of column 15 the values of $\frac{\delta N}{\delta X}$ were again plotted against various values of x in column (11), and the smoothed theoretical frequency curve thus obtained; as shown in Figs. 31 to 39 inclusive.

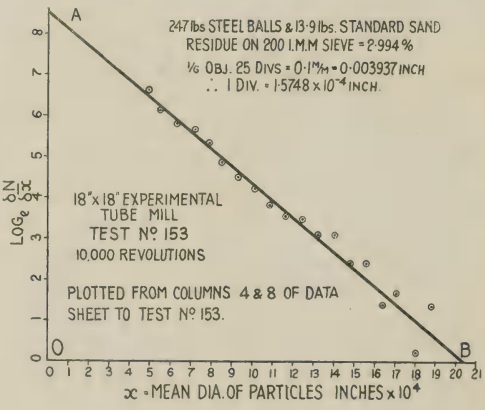


Fig. 48.

A study of these curves will show that in each case the theoretical curve (assuming that the compound interest law is correct) corresponds extremely closely to the experimental zig-zag curve, thus showing that so far as tube mill fine grinding is concerned, in every case yet tried during experiments extending over some years, the compound interest law is almost invariably obeyed.

In conclusion, it will be noticed in column 16 of the data sheets, that, as the time of grinding in the experimental mill is increased, the ratio $\frac{\delta N_1}{\delta X} \Big/ \frac{\delta N_2}{\delta X}$ also increases.

For example, after 600 revolutions of the mill this ratio, $\frac{\delta N_1}{\delta X} \Big/ \frac{\delta N_2}{\delta x}$ is 1·246, after 4,000 revolutions 1·396, and after 10,000 revolutions 1·520.

The importance of this ratio will be developed in Part III of the subject.

Acknowledgments.

This research was carried out in the laboratories of the British Portland Cement Research Association with the aid of financial assistance from the Privy Council for Scientific and Industrial Research and this paper is published with their kind permission.

The drawings were made by Mr. Francis Lindstead, who also assisted in checking the calculations.

Many thousands of microscopic observations in the later stages of the work were made by Mr. William Laurence Gadd, F.I.C.

Help in completing the laborious calculations was afforded by Mr. J. W. Christelow, B.Sc., A.I.C., Mr. Edgar Bowes and Mr. Brand Turner. The work has been part of a programme extending over $2\frac{1}{2}$ years.

Laboratories of the British Portland Cement
Research Association,
Gravesend.

December 10th, 1923.

18 IN. × 18 IN. EXPERIMENTAL TUBE MILL.
DATA SHEET OF TEST No. 145, 600 REVOLUTIONS.
247 lbs. 1 in. Steel Balls and 13·9 lbs. Standard Sand. Residue on 200 I.M.M. Sieve 28·2%
Analysis of Microscopic Measurement of Particles. $\frac{1}{6}$ in. Obj. 25 Divs. = 0·1 mm. = 0·003937 in.
1 Div. = $1{\cdot}5748 \times 10^{-4}$ in.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16
Range of Diameters Divs. of Microscope	Range of Diameters Inches $\times 10^4$ $\delta x = 0{\cdot}7874$.	Mean of Range. Divs.	Mean of Range. Ins. $\times 10^4$ x.	No. of Particles in Range. δN.	$\frac{\delta N}{\delta x}$	$\text{Log}_{10}\frac{\delta N}{\delta x}$	$\text{Log}_e\frac{\delta N}{\delta x} = 2{\cdot}3026 \times \text{Log}_{10}\frac{\delta N}{\delta x}$.	$\text{Log}_e a$. (OA in Fig. 40.)	b. ($\frac{OA}{OB}$ in Fig 40.)	Diam. x. Inches $\times 10^4$	bx.	$\text{Log}_e a - bx$ $\text{Log}_e(ae^{-bx})$	$\text{Log}_{10}\, ae^{-bx} = 0{\cdot}4343 \times \text{Log}_e(ae^{-bx})$	$\frac{\delta N}{\delta x}$.	Ratio of successive Ordinates. $\frac{\delta N_1}{\delta x} \Big/ \frac{\delta N_2}{\delta x}$.
2·75– 3·25	4·331–5·118	3·0	4·724	242	307·3	2·4875	5·7277	6·34	0·21983	0	0	6·34	2·7535	566·9	
3·25– 3·75	5·118–5·906	3·5	5·512	106	134·6	2·1290	4·9022			1	0·21983	6·1202	2·6579	454·8	1·246
3·75– 4·25	5·906–6·693	4·0	6·299	114	144·8	2·1608	4·9755			2	0·43966	5·9003	2·5625	365·2	1·245
4·25– 4·75	6·693–7·480	4·5	7·087	92	116·8	2·0675	4·7606			3	0·65949	5·6805	2·4670	293·1	1·246
4·75– 5·25	7·480–8·268	5·0	7·874	85	107·9	2·0331	4·6814			4	0·87932	5·4607	2·3716	235·3	1·245
5·25– 5·75	8·268–9·055	5·5	8·661	69	87·63	1·9426	4·4730			5	1·0991	5·2409	2·2761	188·8	1·246
5·75– 6·25	9·055–9·843	6·0	9·449	46	58·42	1·7665	4·0675			6	1·3190	5·0210	2·1806	151·6	1·245
6·25– 6·75	9·843–10·63	6·5	10·24	42	53·34	1·7270	3·9766			7	1·5388	4·8012	2·0852	121·7	1·246
6·75– 7·25	10·63–11·42	7·0	11·02	39	49·53	1·6949	3·9027			8	1·7586	4·5814	1·9897	97·66	1·246
7·25– 7·75	11·42–12·20	7·5	11·81	33	41·91	1·6223	3·7355			9	1·9785	4·3615	1·8942	78·38	1·246
7·75– 8·25	12·20–12·99	8·0	12·60	32	40·64	1·6089	3·7046			10	2·1983	4·1417	1·7987	62·91	1·246
8·25– 8·75	12·99–13·78	8·5	13·39	14	17·78	1·2500	2·8782			11	2·4181	3·9219	1·7032	50·49	1·246
8·75– 9·25	13·78–14·57	9·0	14·17	20	25·40	1·4048	3·2347			12	2·6380	3·7020	1·6078	40·53	1·246
9·25– 9·75	14·57–15·35	9·5	14·96	11	13·97	1·1453	2·6371			13	2·8578	3·4822	1·5123	32·53	1·246
9·75–10·25	15·35–16·14	10·0	15·75	14	17·78	1·2500	2·8782			14	3·0776	3·2624	1·4169	26·11	1·246
10·25–10·75	16·14–16·93	10·5	16·54	17	21·59	1·3342	3·0721			15	3·2974	3·0426	1·3214	20·96	1·246
10·75–11·25	16·93–17·72	11·0	17·32	16	20·32	1·3079	3·0116			16	3·5173	2·8227	1·2259	16·82	1·246
11·25–11·75	17·72–18·50	11·5	18·11	9	11·43	1·0580	2·4361			17	3·7371	2·6029	1·1304	13·50	1·246
11·75–12·25	18·50–19·29	12·0	18·90	19	24·13	1·3825	3·1833			18	3·9569	2·3831	1·0350	10·84	1·246
			Total. .	1020						19	4·1768	2·1620	0·9389	8·688	1·246

DATA SHEET OF TEST NO. 146, 1,200 REVOLUTIONS.

247 lbs. 1 in. Steel Balls and 13·9 lbs. Standard Sand. Residue on 200 I.M.M. Sieve 2·903%.
Analysis of Microscopic Measurement of Particles. $\frac{1}{6}$ in. Obj. 25 Divs. = 0·1 mm. = 0·003937 in.
$\therefore$ 1 Div. = $1{\cdot}5748 \times 10^{-4}$ in.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
Range of Diameters Divs. of Microscope	Range of Diameters Inches $\times 10^4$ $\delta x = 0{\cdot}7874$.	Mean of Range. Divs.	Mean of Range. Ins. $\times 10^4$ x.	No. of Particles in Range. δN.	$\frac{\delta N}{\delta x}$	$\text{Log}_{10}\frac{\delta N}{\delta x}$	$\text{Log}_e\frac{\delta N}{\delta x} = 2{\cdot}3026 \times \text{Log}_{10}\frac{\delta N}{\delta x}$	$\text{Log}_e a$. (OA in Fig. 41.)	b. ($\frac{OA}{OB}$ in Fig. 41.)	Diam. x. Inches $\times 10^4$	bx.	$\text{Log}_e a - bx$ $\text{Log}_e(ae^{-bx})$	$\text{Log}_{10}\, ae^{-bx} = 0{\cdot}4343 \times \text{Log}_e(ae^{-bx})$	$\frac{\delta N}{\delta x}$.	Ratio of successive Ordinates. $\frac{\delta N_1}{\delta x}/\frac{\delta N_2}{\delta x}$.
2·75– 3·25	4·331–5·118	3·0	4·724	493	626·1	2·7967	6·4397	7·16	0·231413	0	0	7·16	3·1096	1287	
3·25– 3·75	5·118–5·906	3·5	5·512	289	367·0	2·5647	5·9055			1	0·23141	6·9286	3·0091	1021	1·260
3·75– 4·25	5·906–6·693	4·0	6·299	239	303·5	2·4821	5·7153			2	0·46283	6·6972	2·9086	810·2	1·260
4·25– 4·75	6·693–7·480	4·5	7·087	179	227·3	2·3566	5·4263			3	0·69424	6·4658	2·8081	642·8	1·260
4·75– 5·25	7·480–8·268	5·0	7·874	165	209·5	2·3212	5·3448			4	0·92565	6·2344	2·7076	510·0	1·260
5·25– 5·75	8·268–9·055	5·5	8·661	120	152·4	2·1829	5·0263			5	1·1571	6·0029	2·6071	404·7	1·260
5·75– 6·25	9·055–9·843	6·0	9·449	110	139·7	2·1453	4·9398			6	1·3885	5·7715	2·5066	321·0	1·260
6·25– 6·75	9·843–10·63	6·5	10·24	88	111·8	2·0483	4·7161			7	1·6199	5·5401	2·4061	254·8	1·260
6·75– 7·25	10·63–11·42	7·0	11·02	78	99·06	1·9959	4·5958			8	1·8513	5·3087	2·3056	202·1	1·261
7·25– 7·75	11·42–12·20	7·5	11·81	58	73·66	1·8673	4·2996			9	2·0827	5·0773	2·2051	160·3	1·261
7·75– 8·25	12·20–12·99	8·0	12·60	54	68·58	1·8362	4·2280			10	2·3141	4·8459	2·1046	127·3	1·259
8·25– 8·75	12·99–13·78	8·5	13·39	44	55·88	1·7472	4·0231			11	2·5455	4·6145	2·0041	100·9	1·261
8·75– 9·25	13·78–14·57	9·0	14·17	45	57·15	1·7570	4·0457			12	2·7770	4·3830	1·9035	80·07	1·260
9·25– 9·75	14·57–15·35	9·5	14·96	29	36·83	1·5662	3·6063			13	3·0084	4·1516	1·8030	63·53	1·260
9·75–10·25	15·35–16·14	10·0	15·75	30	38·10	1·5809	3·6402			14	3·2398	3·9202	1·7025	50·41	1·260
10·25–10·75	16·14–16·93	10·5	16·54	19	24·13	1·3825	3·1833			15	3·4712	3·6888	1·6020	39·99	1·260
10·75–11·25	16·93–17·72	11·0	17·32	22	27·94	1·4462	3·3300			16	3·7026	3·4574	1·5015	31·74	1·260
11·25–11·75	17·72–18·50	11·5	18·11	14	17·78	1·2499	2·8780			17	3·9340	3·2260	1·4011	25·19	1·260
11·75–12·25	18·50–19·29	12·0	18·90	19	24·13	1·3825	3·1833			18	4 1654	2·9946	1·3006	19·98	1·261
			Total..	2095						19	4·3968	2·7632	1·2001	15·85	1·260
										20	4·6283	2·5317	1·0995	12·57	1·261

18 in. × 18 in. Experimental Tube Mill.
Data Sheet of Test No. 147, 1,800 Revolutions.
247 lbs. 1 in. Steel Balls and 13·9 lbs. Standard Sand. Residue on 200 I.M.M. Sieve = 1·046%.
Analysis of Microscopic Measurement of Particles. $\frac{1}{6}$ in. Obj. 25 Divs. = 1·0 mm. = 0·003937 in.
∴ 1 Div. = $1{\cdot}5748 \times 10^{-4}$ in.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
Range of Diameters Divs. of Microscope	Range of Diameters Inches × 10^4 $\delta x = 0{\cdot}7874$.	Mean of Range. Divs.	Mean of Range. Ins. × 10^4 x.	No. of Particles in Range. δN.	$\frac{\delta N}{\delta x}$	$\text{Log}_{10}\frac{\delta N}{\delta x}$	$\text{Log}_e\frac{\delta N}{\delta x} = 2{\cdot}3026 \times \text{Log}_{10}\frac{\delta N}{\delta x}$.	$\text{Log}_e a$. ($\frac{OA}{OB}$ in Fig. 42).	b. ($\frac{OA}{OB}$ in Fig. 42).	Diam. x. Inches × 10^4	bx.	$\text{Log}_e a - bx$ $\text{Log}_e(ae^{-bx})$	$\text{Log}_{10} ae^{-bx} = 0{\cdot}4343 \times \text{Log}_e(ae^{-bx})$	$\frac{\delta N}{\delta x}$.	Ratio of successive Ordinates. $\frac{\delta N_1}{\delta x} \Big/ \frac{\delta N_2}{\delta x}$
2·75– 3·25	4·331–5·118	3·0	4·724	505	641·3	2·8071	6·4636	7·46	0·26796	0	0	7·46	3·2398	1737	
3·25– 3·75	5·118–5·906	3·5	5·512	305	387·4	2·5882	5·9596			1	0·26796	7·1920	3·1234	1328	1·308
3·75– 4·25	5·906–6·693	4·0	6·299	258	327·7	2·5154	5·7920			2	0·53592	6·9241	3·0071	1016	1·307
4·25– 4·75	6·693–7·480	4·5	7·087	196	248·9	2·3961	5·5173			3	0·80388	6·6561	2·8906	777·3	1·307
4·75– 5·25	7·480–8·268	5·0	7·874	153	194·3	2·2885	5·2695			4	1·0718	6·3882	2·7742	594·6	1·307
5·25– 5·75	8·268–9·055	5·5	8·661	125	158·8	2·2009	5·0678			5	1·3398	6·1202	2·6579	454·8	1·307
5·75– 6·25	9·055–9·843	6·0	9·449	102	129·5	2·1123	4·8640			6	1·6078	5·8522	2·5415	347·9	1·307
6·25– 6·75	9·843–10·63	6·5	10·24	73	92·71	1·9671	4·5294			7	1·8757	5·5843	2·4252	266·2	1·307
6·75– 7·25	10·63–11·42	7·0	11·02	76	96·52	1·9846	4·5697			8	2·1437	5·3163	2·3088	203·6	1·307
7·25– 7·75	11·42–12·20	7·5	11·81	55	69·85	1·8442	4·2465			9	2·4116	5·0484	2·1925	155·8	1·307
7·75– 8·25	12·20–12·99	8·0	12·60	51	64·77	1·8114	4·1709			10	2·6796	4·7804	2·0761	119·1	1·308
8·25– 8·75	12·99–13·78	8·5	13·39	39	49·53	1·6949	3·9027			11	2·9476	4·5124	1·9596	91·11	1·307
8·75– 9·25	13·78–14·57	9·0	14·17	43	54·61	1·7373	4·0003			12	3·2155	4·2445	1·8434	69·72	1·307
9·25– 9·75	14·57–15·35	9·5	14·96	26	33·02	1·5188	3·4972			13	3·4835	3·9765	1·7270	53·33	1·307
9·75–10·25	15·35–16·14	10·0	15·75	25	31·75	1·5018	3·4580			14	3·7514	3·7086	1·6106	40·80	1·307
10·25–10·75	16·14–16·93	10·5	16·54	17	21·59	1·3342	3·0721			15	4·0194	3·4406	1·4941	31·20	1·307
10·75–11·25	16·93–17·72	11·0	17·32	21	26·67	1·4260	3·2835			16	4·2874	3·1726	1·3777	23·86	1·307
11·25–11·75	17·72–18·50	11·5	18·11	10	12·70	1·1038	2·5416			17	4·5553	2·9047	1·2614	18·26	1·306
11·75–12·25	18·50–19·29	12·0	18·90	15	19·05	1·2799	2·9471			18	4·8233	2·6367	1·1450	13·96	1·308
			Total..	2095						19	5·0912	2·3688	1·0286	10·68	1·307

TEST No. 140, 2,400 REVOLUTIONS.

247 lbs. 1 in. Steel Balls and 13·9 lbs. Standard Sand. Residue on 200 I.M.M. Sieve 1·322%.
Analysis of Microscopic Measurement of Particles. $\frac{1}{6}$ in. Obj. 25 Divs. = 0·1 m.m. = 0·003937 in.
$\therefore$ 1 Div. = $1{\cdot}5748 \times 10^{-4}$ in.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
Range of Diameters Divs. of Microscope	Range of Diameters Inches $\times 10^4$ $\delta x = 0{\cdot}7874$.	Mean of Range. Divs.	Mean of Range. Ins. $\times 10^4$ x.	No. of Particles in Range. δN.	$\frac{\delta N}{\delta x}$	$\text{Log}_{10} \frac{\delta N}{\delta x}$	$\text{Log}_e \frac{\delta N}{\delta x} = 2{\cdot}3026 \times \text{Log}_{10} \frac{\delta N}{\delta x}$.	$\text{Log}_e a$. (OA in Fig. 43).	b. ($\frac{OA}{OB}$ in Fig. 43.)	Diam. x. Inches $\times 10^4$	bx.	$\text{Log}_e a - bx$ $\text{Log}_e (ae^{-bx})$	$\text{Log}_{10} ae^{-bx} = 0{\cdot}4343 \times \text{Log}_e (ae^{-bx})$	$\frac{\delta N}{\delta x}$.	Ratio of successive Ordinates. $\frac{\delta N_1}{\delta x} \Big/ \frac{\delta N_2}{\delta x}$.
2·75– 3·25	4·331–5·118	3·0	4·724	574	729·0	2·8627	6·5916	7·58	0·27564	0	0	7·58	3·2920	1959	
3·25– 3·75	5·118–5·906	3·5	5·512	346	439·4	2·6429	6·0855			1	0·27564	7·3044	3·1722	1487	1·317
3·75– 4·25	5·906–6·693	4·0	6·299	266	337·8	2·5286	5·8223			2	0·55128	7·0287	3·0526	1129	1·317
4·25– 4·75	6·693–7·480	4·5	7·087	208	264·2	2·4219	5·5767			3	0·82692	6·7531	2·9328	856·7	1·318
4·75– 5·25	7·480–8·268	5·0	7·874	174	221·0	2·3444	5·3982			4	1·1026	6·4774	2·8131	650·3	1·317
5·25– 5·75	8·268–9·055	5·5	8·661	146	185·4	2·2681	5·2225			5	1·3782	6·2018	2·6934	493·7	1·317
5·75– 6·25	9·055–9·843	6·0	9·449	113	143·5	2·1568	4·9662			6	1·6538	5·9262	2·5737	374·7	1·318
6·25– 6·75	9·843–10·63	6·5	10·24	79	100·3	2·0014	4·6084			7	1·9295	5·6505	2·4540	284·4	1·318
6·75– 7·25	10·63–11·42	7·0	11·02	66	83·82	1·9233	4·4286			8	2·2051	5·3749	2·3342	215·9	1·317
7·25– 7·75	11·42–12·20	7·5	11·81	51	64·77	1·8114	4·1709			9	2·4808	5·0992	2·2145	163·9	1·317
7·75– 8·25	12·20–12·99	8·0	12·60	43	54·61	1·7373	4·0003			10	2·7564	4·8236	2·0948	124·4	1·318
8·25– 8·75	12·99–13·78	8·5	13·39	41	52·07	1·7166	3·9526			11	3·0320	4·5480	1·9752	94·45	1·317
8·75– 9·25	13·78–14·57	9·0	14·17	35	44·45	1·6479	3·7944			12	3·3077	4·2723	1·8554	71·68	1·318
9·25– 9·75	14·57–15·35	9·5	14·96	28	35·56	1·5509	3·5711			13	3·5833	3·9967	1·7358	54·43	1·317
9·75–10·25	15·35–16·14	10·0	15·75	24	30·48	1·4840	3·4170			14	3·8590	3·7210	1·6160	41·30	1·318
10·25–10·75	16·14–16·93	10·5	16·54	14	17·78	1·2499	2·8776			15	4·1346	3·4454	1·4963	31·35	1·317
10·75–11·25	16·93–17·72	11·0	17·32	13	16·51	1·2178	2·8041			16	4·4102	3·1698	1·3766	23·80	1·317
11·25–11·75	17·72–18·50	11·5	18·11	9	11·43	1·0580	2·4361			17	4·6859	2·8941	1·2569	18·07	1·317
11·75–12·25	18·50–19·29	12·0	18·90	13	16·51	1·2178	2·8041			18	4·9615	2·6185	1·1372	13·72	1·317
			Total..	2243						19	5·2372	2·3428	1·0175	10·41	1·318
										20	5·5128	2·0672	0·8978	7·903	1·317

18 IN. × 18 IN. EXPERIMENTAL TUBE MILL.
DATA SHEET OF TEST NO. 149, 3,000 REVOLUTIONS.
247 lbs. 1 in. Steel Balls and 13·9 lbs. Standard Sand. Residue on 200 I.M.M. Sieve 1·168%.
Analysis of Microscopic Measurement of Particles. $\frac{1}{8}$ in. Obj. 25 Divs. = 0·1 mm. = 0·003937 in.
... 1 Div. = $1{\cdot}5748 \times 10^{-4}$ in.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15	16.
Range of Diameters Divs. of Microscope	Range of Diameters Inches × 10^4 $\delta x = 0{\cdot}7874$.	Mean of Range. Divs.	Mean of Range. Ins. × 10^4 x.	No. of Particles in Range. δN.	$\frac{\delta N}{\delta x}$	$\text{Log}_{10} \frac{\delta N}{\delta x}$	$\text{Log}_e \frac{\delta N}{\delta x} = 2{\cdot}3026 \times \text{Log}_{10} \frac{\delta N}{\delta x}$.	$\text{Log}_e a$ (OA in Fig. 44.)	b. ($\frac{OA}{OB}$ in Fig. 44.)	Diam. x. Inches × 10^4	bx.	$\text{Log}_e a - bx$ $\text{Log}_e (ae^{-bx})$	$\text{Log}_{10} ae^{-bx} = 0{\cdot}4343 \times \text{Log}_e (ae^{-bx})$	$\frac{\delta N}{\delta x}$.	Ratio of successive Ordinates. $\frac{\delta N_1}{\delta x} \Big/ \frac{\delta N_2}{\delta x}$.
2·75– 3·25	4·331–5·118	3·0	4·724	590	749·3	2·8747	6·6193	7·74	0·31285	0	0	7·74	3·3615	2299	
3·25– 3·75	5·118–5·906	3·5	5·512	335	425·4	2·6288	6·0531			1	0·31285	7·4272	3·2256	1681	1·368
3·75– 4·25	5·906–6·693	4·0	6·299	276	350·5	2·5447	5·8594			2	0·62570	7·1143	3·0897	1229	1·368
4·25– 4·75	6·693–7·480	4·5	7·087	198	251·5	2·4005	5·5274			3	0·93860	6·8014	2·9538	899·1	1·367
4·75– 5·25	7·480–8·268	5·0	7·874	161	204·5	2·3107	5·3206			4	1·2514	6·4886	2·8180	657·7	1·367
5·25– 5·75	8·268–9·055	5·5	8·661	102	129·5	2·1123	4·8638			5	1·5643	6·1757	2·6821	480·9	1·368
5·75– 6·25	9·005–9·843	6·0	9·449	77	97·79	1·9903	4·5829			6	1·8771	5·8629	2·5463	351·8	1·367
6·25– 6·75	9·843–10·63	6·5	10·24	60	76·20	1·8820	4·3334			7	2·1900	5·5500	2·4104	257·2	1·368
6·75– 7·25	10·63–11·42	7·0	11·02	54	68·58	1·8362	4·2280			8	2·5028	5·2372	2·2745	188·1	1·367
7·25– 7·75	11·42–12·20	7·5	11·81	38	48·26	1·6835	3·8764			9	2·8157	4·9243	2·1386	137·6	1·367
7·75– 8·25	12·20–12·99	8·0	12·60	29	36·83	1·5662	3·6063			10	3·1285	4·6115	2·0028	100·7	1·366
8·25– 8·75	12·99–13·78	8·5	13·39	29	36·83	1·5662	3·6063			11	3·4414	4·2986	1·8669	73·60	1·368
8·75– 9·25	13·78–14·57	9·0	14·17	24	30·48	1·4840	3·4170			12	3·7542	3·9858	1·7310	53·83	1·367
9·25– 9·75	14·57–15·35	9·5	14·96	14	17·78	1·2499	2·8782			13	4·0671	3·6729	1·5951	39·37	1·367
9·75–10·25	15·35–16·14	10·0	15·75	15	19·05	1·2799	2·9471			14	4·3799	3·3601	1·4593	28·79	1·367
10·25–10·75	16·14–16·93	10·5	16·54	6	7·62	0·8820	2·0309			15	4·6928	3·0472	1·3234	21·06	1·367
10·75–11·25	16·93–17·72	11·0	17·32	10	12·70	1·1038	2·5416			16	5·0056	2·7344	1·1875	15·40	1·368
11·25–11·75	17·72–18·50	11·5	18·11	6	7·62	0·8820	2·0309			17	5·3185	2·4215	1·0517	11·27	1·366
11·75–12·25	18·50–19·29	12·0	18·90	8	10·16	1·0068	2·3182			18	5·6313	2·1087	0·9158	8·237	1·368
			Total..	2032						19	5·9442	1·7958	0·7799	6·024	1·367

247 lbs. 1 in. Steel Balls and 13·9 lbs. Standard Sand. Residue on 200 I.M.M. Sieve 1·330%.
Analysis of Microscopic Measurement of Particles. $\frac{1}{6}$ in. Obj. 25 Divs. = 0·1 mm. = 0·003937 in.
∴ 1 Div. = $1{\cdot}5748 \times 10^{-4}$ in.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
Range of Diameters Divs. of Microscope	Range of Diameters Inches $\times 10^4$ $\delta x = 0{\cdot}7874$.	Mean of Range Divs.	Mean of Range. Ins. $\times 10^4$ x.	No. of Particles in Range. δN.	$\frac{\delta N}{\delta x}$	$\text{Log}_{10} \frac{\delta N}{\delta x}$	$\text{Log}_e \frac{\delta N}{\delta x} = 2{\cdot}3026 \times \text{Log}_{10} \frac{\delta N}{\delta x}$.	$\text{Log}_e a$. (OA in Fig. 45).	b. ($\frac{OA}{OB}$ in Fig. 45).	Diam. x. Inches $\times 10^4$	bx.	$\text{Log}_e a - bx$ $\text{Log}_e (ae^{-bx})$	$\text{Log}_{10} ae^{-bx} = 0{\cdot}4343 \times \text{Log}_e (ae^{-bx})$	$\frac{\delta N}{\delta x}$.	Ratio of successive Ordinates. $\frac{\delta N_1}{\delta x} \Big/ \frac{\delta N_2}{\delta x}$.
2·75– 3·25	4·331–5·118	3·0	4·724	302	383·5	2·5838	5·9494	7·26	0·33364	0	0	7·26	3·1530	1422	
3·25– 3·75	5·118–5·906	3·5	5·512	154	195·6	2·2913	5·2759			1	0·33364	6·9264	3·0081	1019	1·395
3·75– 4·25	5·906–6·693	4·0	6·299	146	185·4	2·2681	5·2225			2	0·66728	6·5927	2·8632	729·8	1·396
4·25– 4·75	6·693–7·480	4·5	7·087	112	142·2	2·1529	4·9573			3	1·0009	6·2591	2·7183	522·8	1·396
4·75– 5·25	7·480–8·268	5·0	7·874	89	113·0	2·0531	4·7275			4	1·3346	5·9254	2·5734	374·4	1·396
5·25– 5·75	8·268–9·055	5·5	8·661	59	74·93	1·8747	4·3167			5	1·6682	5·5918	2·4285	268·2	1·396
5·75– 6·25	9·055–9·843	6·0	9·449	41	52·07	1·7166	3·9526			6	2·0018	5·2582	2·2836	192·2	1·395
6·25– 6·75	9·843–10·63	6·5	10·24	20	25·40	1·4048	3·2347			7	2·3355	4·9245	2·1387	137·6	1·395
6·75– 7·25	10·63–11·42	7·0	11·02	25	31·75	1·5018	3·4580			8	2·6691	4·5909	1·9938	98·58	1·396
7·25– 7·75	11·42–12·20	7·5	11·81	14	17·78	1·2500	2·8782			9	3·0028	4·2572	1·8489	70·62	1·396
7·75– 8·25	12·20–12·99	8·0	12·60	15	19·05	1·2799	2·9471			10	3·3364	3·9236	1·7040	50·58	1·396
8·25– 8·75	12·99–13·78	8·5	13·39	8	10·16	1·0068	2·3183			11	3·6700	3·5900	1·5591	36·23	1·396
8·75– 9·25	13·78–14·57	9·0	14·17	11	13·97	1·1453	2·6372			12	4·0037	3·2563	1·4142	25·95	1·396
9·25– 9·75	14·57–15·35	9·5	14·96	9	11·43	1·0580	2·4362			13	4·3373	2·9227	1·2693	18·59	1·396
9·75–10·25	15·35–16·14	10·0	15·75	7	8·89	0·9489	2·1849			14	4·6710	2·5890	1·1244	13·31	1·396
10·25–10·75	16·14–16·93	10·5	16·54	2	2·54	0·4048	0·9321			15	5·0046	2·2554	0 9795	9·539	1·395
10·75–11·25	16·93–17·72	11·0	17·32	4	5·08	0·7059	1·6254			16	5·3382	1·9218	0·8346	6·832	1·396
11·25–11·75	17·72–18·50	11·5	18·11	1	1·27	0·1038	0·2390			17	5·6719	1·5881	0·6897	4·895	1·396
11·75–12·25	18·50–19·29	12·0	18·90	4	5·08	0·7059	1·6254			18	6·0055	1·2545	0·5448	3·505	1·396
			Total..	1023						19	6·3392	0·9208	0·3999	2·511	1·396
										20	6·6728	0·5872	0 2550	1·799	1·396

18 IN. × 18 IN. EXPERIMENTAL TUBE MILL.
DATA SHEET OF TEST NO. 151, 5,000 REVOLUTIONS.
247 lbs. 1 in. Steel Balls and 13·9 lbs. Standard Sand. Residue on 200 I.M.M. Sieve 0·862%.
Analysis of Microscopic Measurement of Particles. $\frac{1}{6}$ in. Obj. 25 Divs. = 0·1 m.m. = 0·003937 in.
∴ 1 Div. = $1{\cdot}5748 \times 10^{-4}$ in.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
Range of Diameters Divs. of Microscope	Range of Diameters Inches × 10^4 $\delta x = 0{\cdot}7874$.	Mean of Range. Divs.	Mean of Range. Ins. × 10^4 x.	No. of Particles in Range. δN.	$\frac{\delta N}{\delta x}$	$\text{Log}_{10}\frac{\delta N}{\delta x}$	$\text{Log}_e\frac{\delta N}{\delta x} = 2{\cdot}3026 \times \text{Log}_{10}\frac{\delta N}{\delta x}$.	$\text{Log}_e a$. (OA in Fig. 46.)	b. ($\frac{OA}{OB}$ in Fig. 46).	Diam. x. Inches × 10^4	bx.	$\text{Log}_e a - bx$ $\text{Log}_e(ae^{-bx})$	$\text{Log}_{10}\, ae^{-bx} = 0{\cdot}4343 \times \text{Log}_e(ae^{-bx})$	$\frac{\delta N}{\delta x}$.	Ratio of successive Ordinates. $\frac{\delta N_1}{\delta x} \Big/ \frac{\delta N_2}{\delta x}$.
2·75– 3·25	4·331–5·118	3·0	4·724	697	885·2	2·9470	6·7857	8·26	0·376825	0	0	8·26	3·5873	3867	
3·25– 3·75	5·118–5·906	3·5	5·512	368	467·4	2·6697	6·1472			1	0·37683	7·8832	3·4237	2653	1·458
3·75– 4·25	5·906–6·693	4·0	6·299	285	362·0	2·5587	5·8916			2	0·75365	7·5064	3·2600	1820	1·458
4·25– 4·75	6·693–7·480	4·5	7·087	204	259·1	2·4135	5·5573			3	1·1305	7·1295	3·0964	1248	1·458
4·75– 5·25	7·480–8·268	5·0	7·874	162	205·7	2·3133	5·3266			4	1·5073	6·7527	2·9327	856·5	1·457
5·25– 5·75	8·268–9·055	5·5	8·661	106	134·6	2·1291	4·9024			5	1·8841	6·3759	2·7690	587·5	1·458
5·75– 6·25	9·055–9·843	6·0	9·449	81	102·9	2·0123	4·6335			6	2·2610	5·9991	2·6054	403·1	1·457
6·25– 6·75	9·843–10·63	6·5	10·24	59	74·93	1·8747	4·3167			7	2·6378	5·6222	2·4417	276·5	1·458
6·75– 7·25	10·63–11·42	7·0	11·02	54	68·58	1·8362	4·2280			8	3·0146	5·2454	2·2781	189·7	1·458
7·25– 7·75	11·42–12·20	7·5	11·81	31	39·37	1·5952	3·6731			9	3·3914	4·8686	2·1144	130·1	1·458
7·75– 8·25	12·20–12·99	8·0	12·60	26	33·02	1·5188	3·4972			10	3·7683	4·4918	1·9508	89·30	1·457
8·25– 8·75	12·99–13·78	8·5	13·39	20	25·40	1·4048	3·2347			11	4·1451	4·1149	1·7871	61·25	1·458
8·75– 9·25	13·78–14·57	9·0	14·17	18	22·86	1·3591	3·1295			12	4·5219	3·7381	1·6235	42·03	1·457
9·25– 9·75	14·57–15·35	9·5	14·96	11	13·97	1·1452	2·6370			13	4·8987	3·3613	1·4598	28·82	1·458
9·75–10·25	15·35–16·14	10·0	15·75	8	10·16	1·0069	2·3184			14	5·2756	2·9845	1·2961	19·77	1·458
10·25–10·75	16·14–16·93	10·5	16·54	4	5·08	0·7059	1·6254			15	5·6524	2·6076	1·1325	13·57	1·457
10·75–11·25	16·93–17·72	11·0	17·32	5	6·35	0·8028	1·8485			16	6·0292	2·2308	0·9688	9·307	1·458
11·25–11·75	17·72–18·50	11·5	18·11	4	5·08	0·7059	1·6254			17	6·4060	1·8540	0·8052	6·386	1·457
11·75–12·25	18·50–19·29	12·0	18·90	2	2·54	0·4048	0·9321			18	6·7829	1·4772	0·6415	4·380	1·458
			Total..	2145						19	7·1597	1·1003	0·4779	3·005	1·458

247 lbs. 1 in. Steel Balls and 13·9 lbs. Standard Sand. Residue on 200 I.M.M. Sieve 1·548%.
Analysis of Microscopic Measurement of Particles. $\frac{1}{6}$ in. Obj. 25 Dvis. = 0·1 m.m. = 0·003937 in.
∴ 1 Div. = $1{\cdot}5748 \times 10^{-4}$ in.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
Range of Diameters Divs. of Microscope	Range of Diameters Inches $\times 10^4$ $\delta x = 0{\cdot}7874$.	Mean of Range. Divs.	Mean of Range. Ins. $\times 10^4$ x.	No. of Particles in Range. δN.	$\frac{\delta N}{\delta x}$	$\text{Log}_{10}\frac{\delta N}{\delta x}$	$\text{Log}_e \frac{\delta N}{\delta x} = 2{\cdot}3026 \times \text{Log}_{10} \frac{\delta N}{\delta x}$.	$\text{Log}_e a$. (OA in Fig. 47).	b. ($\frac{OA}{OB}$ in Fig. 47).	Diam. x. Inches $\times 10^4$	bx.	$\text{Log}_e a\text{-}bx$ $\text{Log}_e(ae^{-bx})$	$\text{Log}_{10} ae^{-bx} = 0{\cdot}4343 \times \text{Log}_e(ae^{-bx})$	$\frac{\delta N}{\delta x}$.	Ratio of successive Ordinates. $\frac{\delta N_1}{\delta x} / \frac{\delta N_2}{\delta x}$
2·75– 3·25	4·331–5·118	3·0	4·724	291	369·6	2·5677	5·9124	7·62	0·379104	0	0	7·62	3·3092	2038	
3·25– 3·75	5·118–5·906	3·5	5·512	183	232·4	2·3662	5·4484			1	0·37910	7·2409	3·1447	1395	1·461
3·75– 4·25	5·906–6·693	4·0	6·299	150	190·5	2·2799	5·2497			2	0·75821	6·8618	2·9801	955·2	1·460
4·25– 4·75	6·693–7·480	4·5	7·087	113	143·5	2·1568	4·9662			3	1·1373	6·4827	2·8154	653·7	1·461
4·75– 5·25	7·480–8·268	5·0	7·874	78	99·06	1·9959	4·5958			4	1·5164	6·1036	2·6508	447·5	1·461
5·25– 5·75	8·268–9·055	5·5	8·661	50	63·50	1·8028	4·1511			5	1·8955	5·7245	2·4861	306·3	1·461
5·75– 6·25	9·055–9·843	6·0	9·449	46	58·42	1·7665	4·0675			6	2·2746	5·3454	2·3215	209·6	1·461
6·25– 6·75	9·843–10·63	6·5	10·24	31	39·37	1·5952	3·6731			7	2·6537	4·9663	2·1569	143·5	1·461
6·75– 7·25	10·63–11·42	7·0	11·02	22	27·94	1·4462	3·3300			8	3·0328	4·5872	1·9922	98·22	1·461
7·25– 7·75	11·42–12·20	7·5	11·81	17	21·59	1·3342	3·0721			9	3·4119	4·2081	1·8276	67·23	1·461
7·75– 8·25	12·20–12·99	8·0	12·60	15	19·05	1·2799	2·9471			10	3·7910	3·8290	1·6629	46·02	1·461
8·25– 8·75	12·99–13·78	8·5	13·39	8	10·16	1·0068	2·3183			11	4·1701	3·4499	1·4983	31·50	1·461
8·75– 9·25	13·78–14·57	9·0	14·17	8	10·16	1·0068	2·3183			12	4·5493	3·0708	1·3336	21·56	1·461
9·25– 9·75	14·57–15·35	9·5	14·96	6	7·62	0·8820	2·0309			13	4·9284	2·6917	1·1690	14·76	1·461
9·75–10·25	15·35–16·14	10·0	15·75	5	6·35	0·8028	1·8485			14	5·3075	2·3125	1·0043	10·10	1·461
10·25–10·75	16·14–16·93	10·5	16·54	2	2·54	0·4048	0·9321			15	5·6866	1·9334	0·8397	6·913	1·461
10·75–11·25	16·93–17·72	11·0	17·32	1	1·27	0·1038	0·2390			16	6·0657	1·5543	0·6750	4·732	1·461
11·25–11·75	17·72–18·50	11·5	18·11	1	1·27	0·1038	0·2390			17	6·4448	1·1752	0·5104	3·239	1·461
11·75–12·25	18·50–19·29	12·0	18·90	2	2·54	0·4048	0·9321			18	6·8239	0·79613	0·3458	2·217	1·461
			Total..	1029						19	7·2030	0·41702	0·1811	1·517	1·461
										20	7·5821	0·03792	0·01650	1·039	1·460

18 IN. × 18 IN. EXPERIMENTAL TUBE MILL.
DATA SHEET OF TEST No. 153, 10,000 REVOLUTIONS.
247 lbs. 1 in. Steel Balls and 13·9 lbs. Standard Sand. Residue on 200 I.M.M. Sieve 2·994%.
Analysis of Microscopic Measurement of Particles. $\frac{1}{6}$ in. Obj. 25 Divs. = 1·0 mm. = 0·003937 in.
∴ 1 Div. = $1{\cdot}5748 \times 10^{-4}$ in.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
Range of Diameters Divs. of Microscope	Range of Diameters Inches × 10^4 $\delta x = 0{\cdot}7874$.	Mean of Range. Divs.	Mean of Range. Inches × 10^4 x.	No. of Particles in Range. δN.	$\frac{\delta N}{\delta x}$	$\text{Log}_{10} \frac{\delta N}{\delta x}$	$\text{Log}_e \frac{\delta N}{\delta x} = 2{\cdot}3026 \times \text{Log}_{10} \frac{\delta N}{\delta x}$.	$\text{Log}_e a$ (OA in Fig. 48).	b. $\frac{OA}{OB}$ in Fig. 48).	Diam. x. Inches × 10^4	bx.	$\text{Log}_e a - bx$ $\text{Log}_e (ae^{-bx})$	$\text{Log}_{10} ae^{-bx} = 0{\cdot}4343 \times \text{Log}_e (ae^{-bx})$	$\frac{\delta N}{\delta x}$.	Ratio of successive Ordinates. $\frac{\delta N_1}{\delta x} \Big/ \frac{\delta N_2}{\delta x}$.
2·75– 3·25	4·331–5·118	3·0	4·724	638	810·2	2·9086	6·6973	8·56	0·41878	0	0	8·56	3·7176	5219	
3·25– 3·75	5·118–5·906	3·5	5·512	386	490·2	2·6904	6·1949			1	0·4188	8·1412	3·5357	3434	1·520
3·75– 4·25	5·906–6·693	4·0	6·299	283	359·4	2·5556	5·8845			2	0·8376	7·7224	3·3539	2259	1·520
4·25– 4·75	6·693–7·480	4·5	7·087	223	283·2	2·4521	5·6462			3	1·2563	7·3037	3·1720	1486	1·520
4·75– 5·25	7·480–8·268	5·0	7·874	157	199·4	2·2998	5·2955			4	1·6751	6·8849	2·9901	977·4	1·520
5·25– 5·75	8·268–9·055	5·5	8·661	103	130·8	2·1165	4·8734			5	2·0939	6·4661	2·8082	643·0	1·520
5·75– 6·25	9·055–9·843	6·0	9·449	70	88·90	1·9489	4·4875			6	2·5127	6·0473	2·6263	423·0	1·520
6·25– 6·75	9·843–10·63	6·5	10·24	53	67·31	1·8281	4·2094			7	2·9315	5·6285	2·4445	278·3	1·520
6·75– 7·25	10·63–11·42	7·0	11·02	35	44·45	1·6479	3·7944			8	3·3502	5·2098	2·2626	183·1	1·520
7·25– 7·75	11·42–12·20	7·5	11·81	27	34·29	1·5351	3·5347			9	3·7690	4·7910	2·0807	120·4	1·520
7·75– 8·25	12·20–12·99	8·0	12·60	24	30·48	1·4840	3·4170			10	4·1878	4·3722	1·8988	79·21	1·520
8·25– 8·75	12·99–13·78	8·5	13·39	16	20·32	1·3079	3·0116			11	4·6066	3·9534	1·7170	52·12	1·520
8·75– 9·25	13·78–14·57	9·0	14·17	16	20·32	1·3079	3·0116			12	5·0254	3·5346	1·5351	34·29	1·520
9·25– 9·75	14·57–15·35	9·5	14·96	8	10·16	1·0068	2·3182			13	5·4441	3·1159	1·3532	22·55	1·520
9·75–10·25	15·35–16·14	10·0	15·75	8	10·16	1·0068	2·3182			14	5·8629	2·6971	1·1714	14·84	1·520
10·25–10·75	16·14–16·93	10·5	16·54	3	3·81	0·5809	1·3376			15	6·2817	2·2783	0·9895	9·761	1·520
10·75–11·25	16·93–17·72	11·0	17·32	4	5·08	0·7059	1·6254			16	6·7005	1·8595	0·8076	6·421	1·520
11·25–11·75	17·72–18·50	11·5	18·11	1	1·27	0·1038	0·2390			17	7·1193	1·4407	0·6257	4·224	1·520
11·75–12·25	18·50–19·29	12·0	18·90	3	3·81	0·5809	1·3376			18	7·5380	1·0220	0·4439	2·779	1·520
			Total..	2058						19	7·9568	0·6032	0·2620	1·828	1·520

DISCUSSION.

DR. MELLOR:—Dr. Mellor, in proposing a vote of thanks, congratulated Dr. Martin on the success of his work. In a paper on the subject published in the TRANSACTIONS, Vol. 9, Dr. Mellor said that he was held up for want of a relation of the type indicated by Dr. Martin, and in a footnote on that paper it was stated that Mellor and Heath were going to work on the subject. The advent of the War rendered it necessary to lay aside that work. It was, therefore, a special pleasure to note that Dr. Martin had worked out a simple relation showing that the fine particles grow in the cylinder by the same rule which governs the growth of money at compound interest. When the surface factor was built, it was necessary to make a compromise by using a law much simpler than that brought forward by Dr. Martin and the surface factor formula can now be corrected. Dr. Mellor continued: I am afraid that we shall have some trouble. It resolves itself out thus:—We have learned how to use and to get our results with an imperfect foot rule. It may be that it is 11 in. instead of 12 in., but we are all using the *same rule*, so it is not difficult to compare our results. If we get an exact law now and we start again *de novo* we shall have to scrap all our experience with the imperfect rule and, in future, use only the new and correct rule. I am rather afraid that the manufacturers will not agree to accept that, because they are likely to argue that, even though they were to alter their standard, something else may be shortly discovered which will upset the calculations again. I expect that is true, because there are all sorts of complications in the pottery industry, such as variable specific gravities of the flints and various lengths of time for which they must be calcined, and you have even variations in the specific gravity of the coarser flint that is holding up the finer flint in suspension. It is an exceedingly complex subject, and in devising a rule one has to knock off some of these complications. That is just the way in which our present surface factor has been obtained—the one that is in use at the present time.

Dr. Martin mentioned one or two of the things which he has had to fight against in his experimental work, and those of us who are accustomed to this kind of work can read between the lines that he has had a lively time whilst pursuing his investigations. I can quite understand, too, the tremendous cost that it has entailed to bring out this simple law in the way that it has been brought out. I am sure that the law which has been discovered behind Dr. Martin's results will be extremely useful to us if only we can apply it to a substance likely to break up in a uniform way; but with substances like mica and felspar, I am afraid he may find another law that is a little more complicated. If Dr. Martin has done any work on the latter, I hope he may favour us with the results of that work in due course. I have much pleasure in proposing a hearty vote of thanks to Dr. Martin for his valuable paper.

MR. J. A. AUDLEY:—I have great pleasure in seconding this vote of thanks to the author of the paper. Dr. Martin has said that the law itself is very simply explained in Dr. Mellor's book on Higher Mathematics, and he assumes that everyone here, or nearly everyone, is familiar with that book. I can assure Dr. Martin that Dr. Mellor's name is one that is held in very high esteem in this district, and his various publications also, but as to the members of this Society as a body having made any serious study of this particular book, I am afraid that is quite another question. If some of the members were to spend an hour or so in trying to get to the bottom of the formula which Dr. Martin has presented, I am afraid their faces might look as wise as those of some of the experimenters whom he has told us about. There was one gleam of light in the suggestion which Dr. Martin offered that the law corresponds to the law which exists in connection with the increase of money lent out at compound interest. It struck me, when the paper was being read, that one might probably be able to pick up some clearer ideas of what is implied when we have an opportunity of looking over this paper in print. The diagrams were fairly easy to follow. It was interesting to see how nicely in some cases the curve representing this particular law comes out in agreement with the observations and how, when the figures are converted into logarithms, a straight line is obtained. This much was fairly easy to follow, and it gives one some confidence in the law itself. I am fairly confident that when we have an opportunity of looking over the paper in print we may get some real benefit from it. Like Dr. Mellor, I am struck with the great amount of work that has been involved in the experiments, which were carried through so carefully and from which the particular law that has been advanced has been derived. Although it may be that we shall not be able at the moment to make any very great use of the law, I am quite sure that in course of time, it will come to be of considerable use not only to us as pottery workers, but to many other people.

DR. MARTIN:—I thank you very much, Gentlemen, for the kind reception you have given me, and also for your vote of thanks. There is just one little point, and that is that I would wish you to include in this vote of thanks my co-workers. A work of this character is obviously not the work of any one man. I have here with me to-night, two of my co-workers who have done an enormous amount of work—so great an amount, in fact, that the health of one of them has almost broken down under the strain. It might have been that this work could only have been reared on their corpses.

IX.—New Methods of Producing Gas for Industrial Operations.

By

R. Maclaurin.

THERE are three different chemical reactions utilised in the various methods of making Industrial Gas to-day.

A. The first of these consists in making use of the gases evolved from bituminous coals when these are subjected to temperatures above 400°C. in the absence of oxygen.

B. The second is the reaction of air with heated carbon—when the carbon is in large excess, whereby a gas consisting of nitrogen, carbon monoxide and a little carbon dioxide is produced. This is the original Siemens Producer Gas.

C. The third reaction utilised is that which takes place when steam comes into contact with highly heated carbon. In this case the steam is decomposed by the red hot carbon with the formation of carbon monoxide, some carbon dioxide and the setting free of hydrogen. This is what may be called, for want of a better name, the water gas reaction.

It is possible to make gas by combining any two or all three reactions, and in the Mond and Maclaurin producers this is what is done. We will consider the distillation method first :—Since the days of Murdoch, coal has been carbonised by throwing it into horizontal retorts heated to redness. To-day, town's gas is being made in horizontals, judging by the selling price of the gas, as cheaply as by any of the more recently developed vertical retort processes.

From the standpoint of the ceramic industry, however, gas made from coal by external heating is far too costly to demand serious attention, but from the nature of the products evolved, such gas has a very real significance to the ceramic industry. What happens when a lump or a shovelful of coal is thrown on to the sole of a horizontal retort ? Let us consider the case of a layer or a lump of coal three or four inches thick when it touches the hot sole. Rapid evolution of moisture, gas and oil from the surface of the coal in actual contact takes place, and this gas passes up through the cool fuel surrounding it, escaping at the surface, where it makes its way to the ascension pipe. Slowly but surely the heat penetrates another small fraction of an inch, raising it also to the temperature of the retort sole, and after the expiry of several hours the heat will have penetrated to the centre of the piece. By radiation from the

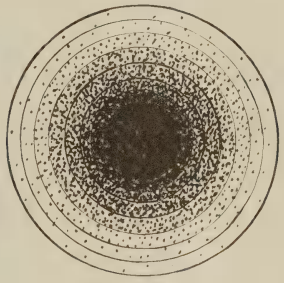
crown of the retort, the top layers of coal have also been getting heated to redness. For some time before carbonisation is completed, there exists, therefore, an uncarbonised core of coal surrounded by layers of coal of gradually increasing temperature.

The gas and oil given off from this core have to pass through layers of hot carbon, and in doing so, a certain amount of decomposition inevitably takes place. This and the subsequent passage of the gases and vaporised oils in contact with the sides and crown of the retort leads to still further decomposition. Eventually, however, the temperature of the core is sufficiently raised to drive off the last of the oily gases, and the coal may then be considered as fully coked. If the temperature of the retort has been kept about, say, 650°C., then it is evident that when the core has reached this temperature a coke will be produced in which neither the outside nor inside have been above 650°C. This coke may contain quite a considerable quantity of volatile matter, say anything between 8 and 10 per cent.; consequently, it will be very readily ignited, partly on account of its porosity and partly on account of this retained volatile matter. This material would, therefore, be an excellent smokeless fuel, if it could be made economically, but it has the physical defect of being rather friable.

If, on the other hand, the temperature of the walls of the retort have been maintained between 1000°C. and 1,200°C., then a very different fuel is obtained. By the time the core has reached 600°C. the outer layer has been heated to possibly 1,000°C. We therefore have a friable, easily ignited core surrounded by a silvery grey exterior, which ignites with difficulty. This is the product generally known as gas work char. The description of what happens in a horizontal retort also holds true in the main for the coke made in vertical or inclined retorts. The principal difference is that, in vertical retorts, the gases given off are in longer contact with coal in the process of being coked; and for a shorter time in active contact with the walls of the retort. In the horizontal retort, if the lump of coal in question has been at the back of the retort, the gas and oil vapour come in contact with the hot crown of the retort for a considerable part of their travel towards the ascension pipe, during which time a certain amount of cracking or breaking up of the oils takes place. If the temperature of the retort is low, decomposition will proceed only to a limited extent, so that the oils obtained will be somewhat nearer the original material of the coal than when high temperatures are used. Low temperature oils are generally more liquid and browner in colour, and altogether less pitchy than high temperature tars. In chemical parlance we say they are more paraffinoid and less aromatic. When the temperature is very high, however, considerable destruction of the oils takes place, so that coals which might give 20 gallons of oil under low temperature conditions do not yield more than 8 or 10 gallons when subjected to high temperature conditions. Matter being

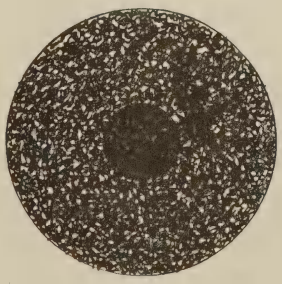
indestructible, the decomposition of the oils increases the volume of the gas.

Consider now the condition of a piece of coal gradually heated up from normal temperatures to 600°C. by some process in which it is only subjected to very gradually increasing temperatures.



A

B



C

FIG. I

In this case the penetration of the heat will go slowly in from outside to centre and there will not be at any time a very big

difference in the inside and outside temperatures. The gases will be slowly evolved as the temperature rises and until a temperature above 350°C. is reached no fusion is likely to take place. When the fusion does begin much of the gas has already been driven off from the coal. The rate of fusion and evolution of gas is now so gradual that there will be little possibility of bubbles being formed. The further increase of temperature, therefore, leads to coking, but in this case without formation of a bubble structure.

Figure 1 endeavours to show the temperature gradients in pieces of coal heated under these three conditions:—

A. indicates a piece of coal carbonized in a high temperature retort. B. a piece of coal in a low temperature retort. C. a piece of coal heated very gradually, as in a Maclaurin Producer.

The black centre is supposed to illustrate the core of coal still at 400°C., and the lighter shades of the outer layers indicate the temperatures existing under the three conditions.

Figure 2 endeavours to show the distribution of heat in the charge in a horizontal high temperature retort about four hours after charging, the black core still being visible.

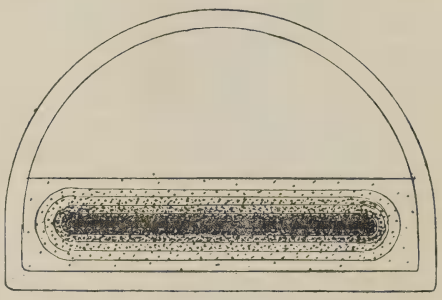


FIG. II

Figure 3 shows the distribution in a vertical retort, A. being a section of the retort and B. a portion of the vertical retort to a larger scale. The struggle between the horizontal and vertical retorts for the mastery is still proceeding, and at the present day horizontals claim to be able to produce gas at a lower price than verticals.

Gas works managers being human, and recognising that gas for which they can get 8d. to 1/- per therm is a very much better paying product to make than tar, even at 5d. per gallon, have, naturally, concentrated upon the production of gas under high temperature conditions. Furthermore, smokeless fuel obtained by carbonising at 600°C. when heated up to 800° or 900°C., gives off

a further quantity of gas, in this case principally hydrogen, but this gas at 8d. to 1/- per therm is also of very much more value than the weight of coke lost for sale. Again, the increase in the temperature of the retorts from say 700°C. to 1,000°C. reduces very materially the length of time required to carbonise the coal fully, and this involves a considerable saving.

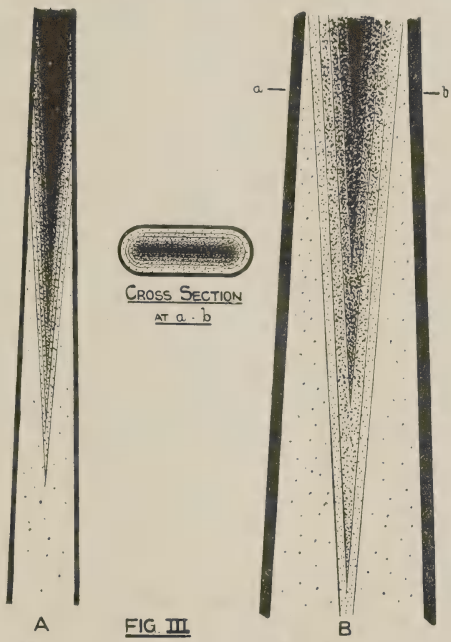


FIG. III

These are the primary reasons why the gas works' manager favours high temperature carbonisation, and at the moment, I do not see that the arguments advanced by the advocates of low temperature carbonisation are sufficiently sound to induce him to alter his practice, so long as the heat has to be applied externally. By low temperature distillation there is obtained in the gas evolved from 10 to 14 per cent. of the heat of the coal ; by high temperature distillation from 20 to 25 per cent. We have now considered shortly and imperfectly how the gas and oil are affected by increasing temperatures, and also how the coke is affected. In the case of coke ovens, the coal is kept for a much longer period in the oven, so that the high temperature of the walls may penetrate to the centre. This coke is, therefore, very hard and also very difficult to ignite.

Gas was first made in horizontal retorts heated to comparatively low temperatures, and with the progress of the years, the temperatures were steadily increased. The next advance in the

manufacture of an industrial gas was the Coke-Air Gas Producer. This type of producer makes use of the reaction between a limited supply of air and an excess of highly heated carbon. Taking air as a mixture of 1 volume of oxygen and 4 volumes of nitrogen, the reaction aimed at can be expressed as :—

$$O_2+4N_2+xC = 2CO+4N_2+yC.$$

In practice a certain quantity of carbon dioxide is always produced.

Good producer gas may contain from 29 to 33 per cent. of carbon monoxide. This gas is an excellent gas for steel work furnaces, where very high temperatures are required, but is a very unsuitable gas for the ceramic industry, where the gases come into contact, in the early stages of firing, with very large quantities of cold ware. Under such conditions the flame of this gas is very easily put out and it would be a very easy matter to blow a large quantity of the heating value of such a gas into the air unutilised.

In the Siemens Producer, air is drawn through a thick bed of coke, and the hot gas passing from the surface of the coke is met by, and burned with, a secondary supply of air entering above the coke level. The objections to this system of making industrial gas are :—

1. For high efficiency the gas must be used hot.
2. The gas is of low calorific value (about 130 B.T.U.) and therefore cannot be distributed economically.
3. The gas is very easily extinguished.
4. Owing to the high temperature of the fire, clinkering troubles are considerable, unless specially selected fuels are used.

The first advance in producers, to overcome these disadvantages, was the introduction of steam with the air. This brings into use the reactions between water vapour and highly heated carbon. At very high temperatures the reaction is chiefly :—

$$H_2O + C = CO+H_2$$

At low temperatures :—

$$2H_2O+C = CO_2+2H_2$$

In practice both reactions occur.

The introduction of the steam overcomes, to a considerable extent, all the objections to the pure air producer. In the first place it reduces the temperature of the fire and so avoids clinkering difficulties. It increases the calorific value of the gas by 30 to 40 B.Th.U. per cu. ft. It provides a gas with a considerable percentage of hydrogen. The hydrogen enables the gas to keep alight when a pure coke air gas would be extinguished. For many purposes this gas is superior to coke air gas, but as it contains from about 45 to 50 per cent. of nitrogen, it is not suitable for mixing with towns gas, nor for use where very high temperatures are required, such as for welding. For this purpose a pure water gas

has for many years been used.

For this, special types of producers are run in two stages. The temperature of the fuel is first raised by a pure air blast to a very high temperature, the blow gas made being either utilised or blown to waste ; then the air is shut off and steam is introduced, the gas being made "on the run" being passed to gasholders either for mixing with towns gas or for use for welding. The calorific value of this gas is round about 300 B.Th.U. It contains about 50 per cent. of hydrogen and about 40 per cent. to 43 per cent. of carbon monoxide, the balance being made up of carbon dioxide and nitrogen. The thermal efficiency of the process is rather low, but the gas is of particular use where a short fierce flame is desired, as in welding. The shortness and high temperature of the flame of this quality of gas make it very unsuitable for use in firing ware, owing to the local high temperatures created. Its cost also rules it out. Clinkering troubles are also common. This gas is now largely used for mixing with towns gas, either after carburetting or without. It can be produced more cheaply than towns gas, but its higher percentage of carbon monoxide is considered in some quarters to be objectionable. The fact that the gas is not made continuously is also troublesome, blow gas and run gas being made at intervals of a few minutes.

The work of Beilby, and later of Mond, showed the possibility of working producers continuously with a high steam passage, and at the same time recovering a considerable part of the nitrogen as ammonia. The ability displayed in developing this process on sound lines never obtained the commercial reward which the labours merited. The gas has a calorific value of between 140 and 170 B.Th.U.., and is, therefore, quite suitable for most industrial purposes. Its hydrogen content is, however, relatively high, and this means that a large quantity of heat is carried away in the latent heat of the steam formed when it is burned. The quantity of steam used per ton of coal gasified originally was very high, but recently this has been considerably reduced. Against these disadvantages, however, has to be set the fact that clinkering troubles are practically abolished, and that there is recovered from 70 to 90 lbs. of ammonia as sulphate, the value of which helps materially to meet the costs of running the plant even when allowing only ¾d. per lb. for the ammonia. The recent rise in the price of coal without a corresponding increase in the price of ammonia, unfortunately, has placed this process in a less favourable position than it would otherwise have been.

For the ceramic industry the gas will be hardly as suitable as gas made in producers with a lower steam passage, partly because of the relative shortness of the flame and partly because of the greater amount of heat carried away in the gases going to the chimney. Since the beginning of this century, considerable attention has been given in the Gas Industry to the development of new types of retorts to replace the horizontals, and several successful

batteries of vertical retorts have been in use now for many years. The great difficulty in carbonising coal in externally heated retorts is the difficulty of transferring the heat to the centre of the mass of coal. The width of all such retorts is, therefore, necessarily limited.

The more recent work on verticals has been in the direction of steaming the charge, thereby making use of the water gas reaction as well as the distillation reaction. The effect of this steaming is to reduce the calorific value of a pure distillation gas, which is nominally between 500 and 600 B.Th.U. per cu. ft. down to 400-450 B.Th.U. due to the admixture of the 300 B.Th.U. water gas. For most heating operations this is no disadvantage, and the tendency to-day is to carry this to its economic limits. It has the very great advantage of increasing the oil yields and giving a more fluid oil. This is due to the effect that the highly heated steam and larger volume of hot gases have in causing a better transference of heat and also in sweeping the oils more rapidly out of the retorts. The ammonia yield is also increased, but the coke yield is reduced, while its ash content is increased. For each coal there is a point to which it is advisable to steam in order to get the best value out of the retorts.

For the last twenty years a number of chemists and engineers have been striving to carbonise coal in such a way as to obtain gas and smokeless fuel as a paying proposition. For more than 20 years I have been working at methods of heating houses smokelessly, but at first my efforts were connected with the improvements of the stoves, fires and ranges in domestic use. Experience, however, taught me how useless it was to invent any scheme which involved any change or demanded any extra attention or intelligence on the part of the domestic housewife. The education of the public is not a paying commercial undertaking. Smokeless fuel did not appear to make any extra demands on the intelligence of the domestic, and so I was converted to the advisability of making the provision of this the chief objective.

My early gas and oil work training was naturally of considerable use to me in this connection, with the result that, shortly before the war, I filed a patent for the production of gas, oil, ammonia and coke. I was fairly familiar with the work of others, but I felt that, if coal was to be carbonised successfully for the provision of a cheap smokeless fuel, it must be done on a big scale, in large-sized units, whereby the labour, interest and depreciation charges could all be reduced to a minimum. I, therefore, conceived the idea of endeavouring to make smokeless fuel in a plant somewhat on the lines of the blast furnace. Recognising the difficulties of dealing with coking coal in such a plant, I set myself to overcome these. Looking back now on the many complicated drawings I made out at this time, and comparing them with the simplicity of the finished plant, I recognise how slowly the human mind works to the solution of a problem. The difficulty which loomed most

largely in the foreground was to deal with a coking coal and prevent this from binding itself together into an impenetrable mass.

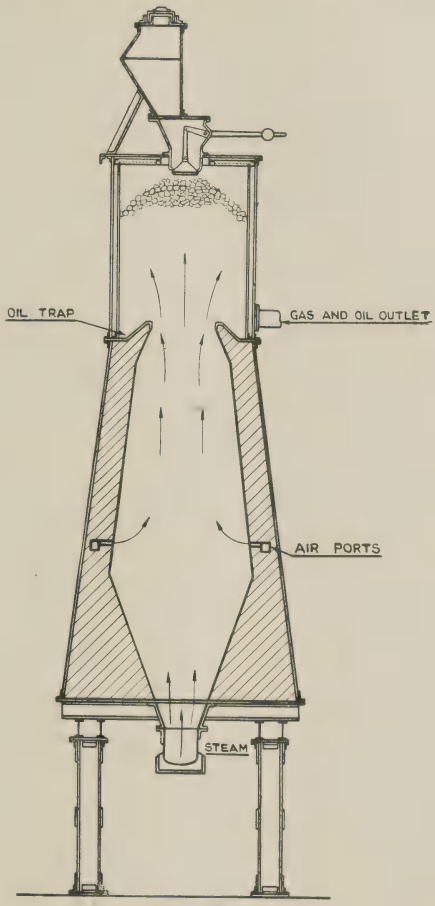


Fig. 4.

With cannel coal I did not consider any serious difficulty was likely to arise, as the well for condensing oils (see Fig 4) would trap these and prevent them flowing down into the lower part of the furnace; but with coking coals, if intumescence should take place, trouble was almost certain to arise. So certain of this were some of my friends that they warned me that I would be lucky if the plant managed to run for a fortnight. My hope of succeeding was largely based on the statement by Percy, that coking coals, when heated slowly for a prolonged period, lost their power of coking. I took the precaution, therefore, of providing for a long period of heating by

making the plant large enough to ensure that the coal would be a long time within it before reaching the full coking temperature. I was in the unfortunate position of not being able to devise any small scale experiment, which, should it fail, would convince me of the folly of proceeding with a large scale trial. I felt that the difficulties on a small scale trial were so great that I would almost certainly fail, but I was convinced that there was a prospect of success if the scale were large enough. Another very pertinent objection raised at this time was, that if the coal really lost its power of coking as I expected, then in place of obtaining a useful coke, I should obtain a material which would readily crumble to powder. I recognised the validity of this argument, but felt hopeful that it would be possible so to time the running of the plant as to avoid the intumescence while yet escaping extreme friability.

Standing beside a large sized double producer starting up for the first time with possibilities of a serious explosion following any mistake in judgment, and recognising that failure meant the loss of other people's money and your own reputation, is not a thoroughly enjoyable sensation. Fortunately, from the very first, the actual working of the plant went as smoothly as could be. The difficulties anticipated did not occur, and this was very fortunate, for a great many difficulties, which had not been anticipated, did occur. I will not, however, trouble you with these, as they had principally to do with the quality of the gas as an illuminating gas; with the unexpected nature of the oils obtained; and with the sparkiness of the smokeless fuel produced.

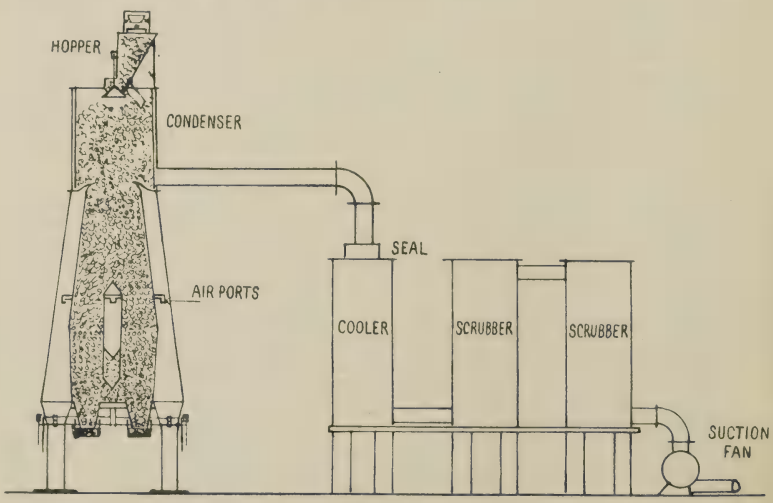


Fig. 5.

I shall now describe the plant, not as originally devised, but

in the form in which it has been tested out on a full-sized unit scale at Grangemouth (see Fig. 5). The original experimental smokeless fuel plant was erected at the Port Dundas Electricity Station of the Glasgow Corporation, and the experimental work was carried out with their generous assistance. The plant at Grangemouth is about 45 ft. high and at the widest portion it is 8 ft. wide. It is built square in place of circular to allow of greater uniformity in the air distribution. The air blast is introduced about 12 ft. above the discharging doors, which are four in number. The blast is distributed through a large number of narrow brick ports in the side walls and also in a dividing wall which is carried across the plant for the purpose of ensuring more uniformity in the distribution. The plant tapers upwards above these ports until the opening is reduced to about 3′ 6″. At this point the brick work stops and a cylindrical iron tank 8 ft. wide and about 10 ft. high completes the main part of the structure. The bottom of this tank is projected upwards towards the centre so as to provide a well, within which oil and water can collect. Within this outer cylinder a second cylinder, about 4″ less in diameter, is placed. In place of resting on the bottom this cylinder rests on supports, which raise it about an inch or so from the bottom, thereby leaving a free passage for the oil. This cylinder is termed the condenser, and on it is fixed the charging bell, and a small hopper capable of holding approximately one ton of coal. This small hopper, where a battery of units is in operation, would be fed from store hoppers, which in their turn would be kept filled by a travelling conveyor and elevator.

The discharge is by the four doors at the bottom. Here the coal rests on a cutter plate, which can be moved by a lever, and the escape of gas is stopped by a small water seal which can be swung into place by the movement of a second lever. The movements are very simple, and the arrangement allows the workman to see and control the discharge. The discharging doors are about 6 ft. from the ground, so that the coke or residue can be dropped into tubs or on to a conveyor. The plant, when full, holds about 30 tons of fuel. After the plant has been started, working is continuous. Coal is put in at the top at the rate of about 1 ton per hour, and the equivalent of coke or residue is withdrawn at the bottom.

If the plant is being changed over from working for coke to working to complete gasification, the only alteration required is in the adjustment of the valve controlling the air blast and the valve controlling the gas passing away. The control of these valves allows the operator to obtain either a black smokeless fuel or a hard grey coke, or an ashy residue. The plant, though continuous, can be considered to be divided into five zones : a cooling zone, a combustion zone, an ammonia making zone, a distillation zone, and a condensing zone. In the cooling zone, the combustion zone, and the distillation zone, the three reactions which we have

already described take place.

The cooling zone extends from the discharging doors upwards to the air ports. Steam is introduced at the doors and this cools the coke or residue. The steam gets superheated and is finally decomposed by the hot fuel below the air ports. In this zone the water gas reaction is taking place. At and above the air ports, combustion takes place involving the production of a coke-air gas, although the further breaking up of steam into hydrogen, carbon monoxide and carbon dioxide is also taking place. The temperature and conditions existing immediately above the combustion zone are suitable for the generation of ammonia, and when working to exhaustion, a considerable quantity of ammonia is produced in this zone. Above this, where the temperature has fallen to about 500°C., we touch the distillation zone. Now I wish to direct your attention very particularly to what is taking place in this zone, and to compare it with what happens when coal is heated in a low or high temperature externally-heated retort, as the quality of the resultant cokes and oils is very materially affected by the nature of the heating to which the fuel is subjected. Compare the condition of a piece of coal when it reaches the position in the producer where it is surrounded by combustion gases at a temperature of 650°C. with the conditions of a piece of coal thrown into a horizontal or vetical retort at 650°C. In the latter case the core of the fuel is cold, and the outer layer will be raised to 600°C. before the core is heated to 300°C. In the fuel entering the zone of 650°C. in the Maclaurin plant, the core of the coal is probably already well above 500°C., for the coal will have been from 10 to 15 hours within the plant, during which time heat has been slowly penetrating to its centre. The oils contained will, therefore, have been largely driven off in the regions above this, and as they have not had to pass out through layers of highly heated carbon, or come into contact with highly heated retort walls, it is evident that very little decomposition will have taken place. Moreover, as the rate of evolution of these oils and gases is very slow, the gases have plenty of time to escape, and so there is practically no rupturing of the cellular structure of the coal. Other experimenters have shown that the intumescing material in the coal begins to soften and break up after the non-coking oils have been given off; so that, in the Maclaurin plant, these lighter oils are almost all away before the material which binds the coal into coke begins to exert its influence. Here again the change proceeds very gradually, and in place of the coal completely softening, losing its shape and binding together, it only becomes sufficiently plastic to take the impress of the pieces of coal surrounding it. This applies to coal which, in a coke oven, would make good coke. From coals that would not by themselves form a coke in a coke oven, good coke can be obtained in the Maclaurin plant. The reason for this is that large coal is used in the Maclaurin plant, and therefore, the cellular fabric of the coal is not destroyed,

as it is by grinding for use in coke ovens, and whereas the amount of binding agent in the low coking coals is not sufficient to bind together a lot of small granules of coal not in intimate contact, there is, in almost all bituminous coals, sufficient binding material to penetrate and bind into one structure, cellular material in very close contact, as such material is in the unground coal. Coal heated in a high temperature vertical, a low temperature vertical, and a Maclaurin Producer may be considered as being present in layers like those of an onion. The layers would be at different temperatures. When the centre has reached 400°C. the outer layers in the three cases may be taken at 1,000°C. for the high temperature retort, 650°C. for the low temperature retort, and probably 450°C. for the Maclaurin retort. (See Fig. 1.)

The oily vapours are caught in the ascending stream of hot gases as they leave the surface of the coal in the Maclaurin plant, and pass upwards to the constriction, where they are moving with a fair velocity. Above this point they rapidly spread out through the comparatively cold incoming fuel, while the velocity as well as the temperature decrease quickly. Condensation of the oils, therefore, takes place, and also of water, and these condensates trickle down into the well of the condenser. Here they accumulate, passing below the inner cylinder, which acts as a seal and so forces the gases to rise through the incoming coal, and down between the space between the inner and outer cylinder, where further condensation takes place. After the oil and liquor in the well have once reached the level of the gas exit pipe near the bottom of the outer cylinder, gas, oil, and water flow along this pipe to the hydraulic main, coolers, and scrubbers, where the remainder of the oil and the ammonia and the bulk of the water are condensed out. Nothing but clean, cool gas, therefore, passes to the suction fan, which delivers it to the points of utilisation. When working for coke the gas leaves the plant between 60°C. and 80°C. and as the coke being discharged is also cooled, the heat losses in the process are remarkably small.

The heat necessary to maintain the temperature is supplied by the combustion of a small quantity of the carbon of the fuel, but the carbon monoxide formed is afterwards available in the gas produced. A few words on the bye-products may here be desirable, as their value has a very direct bearing on the cost of the gas.

Coke. The coke generally resembles in size and appearance the lumps of coal going into the plant. The higher the coking index of the coal the more it is liable to change in appearance due to softening. In non-coking and low-coking coals a considerable quantity of the limey and pyritic bands break off and become concentrated in the dust. The large coke obtained by screening, in consequence, often contains considerably less ash than would be anticipated from the ash in the coal used. Stoney matter can also

be readily separated out after carbonisation by the difference in specific gravity of the coke and stone.

The fuel made, as already explained, can be varied according to the blast used. A black and easily ignited fuel is obtained, or, at will, a silvery grey furnace coke. Both types of fuel are hard; generally much harder than the original coal. The average resistance to crushing of 34 samples tested amounted to 804 lbs. per square inch. The volatile matter, however, differs very little in these two fuels, being usually between 5 per cent. and 3 per cent. The change from black to grey is apparently due more to a physical change than to any appreciable difference in the percentage of volatile matter. Several hundred tons of this coke have gone through the blast furnaces in Scotland.

Oil: Values. The oil yields range from a very few gallons per ton, with strongly coking coals of low volatile content, to 30 and 40 gallons per ton with coals of a canneloid nature. The average yield for bituminous coals lies between 14 and 20 gallons. The oil yields are the highest possible from the kind of coal used, as less decomposition of the oils takes place than in any plant hitherto known. Because of this a new series of commercial products is obtainable from the oils. The crude oil is usually a thick brown liquid with a setting point between 20°C. and 30°C. Considerable discussion has taken place over the value of low temperature oils. These oils are readily separable without distillation into four distinct portions. The first portion is an asphaltic portion, somewhat similar to bitumen or asphalt. The second portion is more resinous, and consists largely of phenols of high boiling point, the value of which ranges between 3/6 and 4/- per gallon. The third portion consists of the known phenols from carbolic to the xylenols. These have a value between 1/6 and 2/- per gallon at present values. The phenolic portions have been used for the manufacture of resins and lacquers. The total percentage of phenols obtainable is from 4 to 10 times greater than from high temperature tars. The fourth part of the oil is a neutral oil, rich in paraffin wax. The lighter portions can be used for lubrication, Diesel oils, or for motor boats, etc., the heavier for the recovery of paraffin wax, or the whole of the neutral oil can be converted into a lubricating grease which has been used satisfactorily for motor axles, stauffert cups, for ball bearings running at 1,700 r.p.m., and for shaft lubrication, and yet is so cheap as to make its use possible on colliery tubs. The oil contains practically no petrol. The simplest treatment, however, is to make two products only, viz.:—refined tar and creosote oil. Present values of refined tar and creosote run between 7d. and 10d. per gallon.

Ammonia. The liquors obtained differ from ordinary gas work and coke oven liquor, in being free from ferrocyanides and sulphocyanides. Instead they contain polyhydric phenols, one of which gives a blue colour with iron, and another gives a quinone

oxime, somewhat similar to resorcinol green. The green is interesting. Used as a pigment it gives green shades. It also is interesting, as being the first dye to be taken direct from ammoniacal liquors. The ammoniacal liquors also give a black product, which can be used as a drop black; and a brown pigment, which is in demand as a paper stain. The ammonia can be obtained as white sulphate, by ordinary gas-work methods. The yields are from 16 to 80 lbs., according to the nitrogen in the coal used, and whether the plant is run for coke or for complete gasification.

Having described the Maclaurin carbonising plant and explained how gas is produced in it, we will now consider the probable cost of this gas; because for the burning of bricks and clay goods generally, gas, if it is to be of any interest, must be very cheap. Towns gas and water gas must be ruled out as far too costly, if for no other reason. We can, therefore, confine ourselves to the consideration of the items which go to making up the cost of producer gas in any of its varieties. Roughly these may be taken at something like the undernoted figures per ton of coal when working on a very large scale.

	Ordinary Producers	Maclaurin Producers
Coal per ton	20/-	20/-
General charges, stores, taxes	2/-	2/-
Steam 1,000 and 400 lbs. of steam per ton of coal	1/3	6d.
Labour per ton	1/6	1/6
Interest, depreciation, repairs at 25% on the capital cost	2/-	2/6
Supervision	6d.	6d.
	27/3	27/-

We, therefore, see that at the present time, if we had nothing else to rely on, the efficiency or availability of the gas from one ton of coal would have to make up for the 27/- spent on its production. The heat in the gas, however, from one ton of coal is not equal to the heat in the coal itself, so that this deficiency has also to be compensated. To follow this more clearly it will be advisable to explain the term "Therm" which I shall have to use frequently hereafter. Until recently, the usual heat unit in use was the British Thermal Unit, viz. :—the amount of heat necessary to raise one lb, of water 1°F., but just as the "Watt" was too small an electric unit for convenient use on an industrial scale, so is the British Thermal Unit. In place, however, of using 1,000 B.Th.U. to correspond to the Kilowatt, 100,000 B.Th.U. have been chosen as the most convenient and this unit has been named the "Therm." You will realise better what a Therm means by fixing in your mind that 1,000 cu. ft. of ordinary producer gas contains approximately 1½ therms, while 1,000 cu. ft. of Towns

Gas contains about 5 therms. Coal containing 12,500 B.Th.U. per lb. will contain 280 therms per ton. If this coal cost 23/4 per ton each therm in it will cost exactly 1d. At 20/- per ton, each therm would cost ·85d. The same coal put through a producer working at 75% efficiency would give 210 therms in the gas, and as the cost of these 210 therms would be round about 27/-, the cost of each therm in the gas would be approximately 1·5d. Against this higher cost, there are, of course, labour savings and increased efficiency to be taken into account. Up to the present, however, I think I am right in stating that the ceramic industry is not, to put it mildly, enthusiastically in favour of the use of gas.

The cost of gas produced by the different processes described when working on a large scale may be taken at :—

		Cost per Therm.
1.	Distilling coal in closed retorts ..	6d. to 3d.
2.	Gasifying coal in water gas plant	4d. to 2d.
3.	Gasifying coal in non-recovery producers	2½d. to 1½d.
4.	Gasifying coal in Maclaurin producers	1¼d, to ¾d.
5.	In coal according to its quality ..	2d. to ½d.

The high costs of gas by the distillation methods is due to the nature of the plant, which involves high interest, depreciation and repair charges amounting in most cases to as much as 2d. per therm on the gas produced. The high water-gas costs are due to the relatively low thermal efficiency of the process, and to high steam charges. The comparatively lower cost of producer gas is due to the relatively low capital cost. The comparatively high cost of non-recovery producers is due to all the interest and working charges having to be borne by the gas.

In recovery producers the relatively high capital costs and high steam consumption is compensated by the return from the ammonia and tar, and, therefore, under certain conditions of the market, recovery producers may be able to produce gas under 1½d. per therm. In the Maclaurin producers the interest, repairs and depreciation charges and working charges including steam are very low, and these are recovered in the returns obtained for the oil and ammonia, when working for complete gasification, and from the coke also when working for this. The explanation is obvious. The value of the oil obtained is weight for weight several times greater than the value of the original coal. The value of the coke is also considerably above that of an equal weight of coal, while the ammonia obtained brings in a considerable revenue without in any way detracting from the heating value of the products.

For many years the value of oil has been, when estimated on its fuel value, two to three times as valuable as coal, whereas, if estimated on a pitch or creosote oil basis it will be to-day six to seven times as valuable. Coke suitable for furnace work has been from 1½ times to twice the value of coal over long periods. To-day, it is from 2 to 3 times as valuable. To-day's prices are,

however, abnormal, being largely due to the trouble in the Ruhr.

The normal type of producers are producers of gas and consumers of coke. The Maclaurin plant differs in being a producer of coke as well as of gas.

Costs of Gas. It is evident that the cost of producing gas will vary with the market value of the bye-products. The Maclaurin plant can be run under so many conditions that some adjustment to meet fluctuating market conditions is possible. For example, if the price of coke were to fall very low, the same plant could be run completely gasifying the coal. In this case very poor coals could be used, or cannel coals rich in oil, if these are obtainable in the district. In this case the oil and ammonia and gas yields would be increased but no coke would be obtained.

To indicate some of the methods of working the plant, I will suppose that a brick works or large pottery is able to obtain large clean coal at 20/- per ton, washed trebles at say 18/- per ton, run of mine coal at say 16/- or an ashy coal containing 20 per cent. of ash at 13/- per ton. Then, working with any of these fuels gas could be produced under 1d. per therm.

The following table will indicate the quantities of the different products obtainable from three typical fuels :—

		COMPLETE GASIFICATION	
	Clean Coal for Coke production	Coal with 20% Ash	Blaes or Colliery refuse, 50% Ash.
Coke, cwts.	$10\frac{3}{4}$	nil	nil
Oil (dry) ..	14·34 gals.	15 gals.	8 gals.
Sulphate of Ammonia	18 lbs.	64 lbs.	24 lbs.
Gas containing ..	77 therms	164 therms	90 therms

If we allow 5d. per gallon for the oil, $\frac{3}{4}$d. per lb. for the ammonia, 28/6 per ton for the coke, and 1d. for each therm in the gas in all of the above cases, the prices which one could afford to pay for the fuel would be 21/9 for the clean coal, 16/11 for the ashy coal, and 5/4 for the blaes or colliery refuse. At such prices the coal is at a higher value relative to the values placed upon the bye-products than usually obtains. At the present time, for example, the coke made from a coal costing 21/9 would fetch over 40/- per ton in place of 28/6 as taken, and the oil would fetch 7d. per gallon in place of 5d. as taken. The net cost of the gas, therefore, can come well under 1d. per therm, after providing 25 per cent. on the capital cost for interest, repairs and depreciation.

Figures have been made out to show how to deal with the complete output of a colliery in a Maclaurin plant, and in this case by utilising the duff and valuing this at 6/- per ton, the gas can be made at a cost of about three farthings per therm. These calculations are based on a battery of 10 units or more running continuously at full load for at least 300 days per annum. With a decrease in the size of the battery, the working costs and interest costs increase. The costs are further increased when the demand for gas is not

uniformly spread over the 24 hours, and though the plant can readily adapt itself to loads varying within very wide limits, the interest and working charges naturally increase the lower the load.

The capital cost of a battery of two units capable of carbonising 40 tons of coal per day works out at about 10/- per ton of coal carbonised per annum. On a ten unit battery capable of carbonising 200 tons per day, the capital cost comes down to about 8/- per ton at present-day prices. The working costs per ton decrease fairly rapidly from a two unit to a six unit battery, but for any further increase the savings are not very marked. The figures used for coke making are not selected results, but are the average of four separate tests in which measurements were made on 450 tons of coals.

Now, while I am not prepared to agree with the Potter who will have nothing to do with gas under any conditions, I am inclined to believe that there has been more in his objections to gas than is apparent on the surface. With a therm in coal at 1d. and a therm in gas at 1½d., a considerable increased efficiency is required of the gas, and we have seen that the only gases cheap enough to be considered are hardly the most suitable. With gas at 1d. per therm, the inducement to consider gas is certainly increased, but if at the same time the quality of the gas is more suitable for the purposes required, then a strong case for reconsideration is made out.

I am not going to make out that the gas made in the Maclaurin plant, when running to complete gasification, is very different from the gas made in other producers, for it cannot differ very far from the gas made in any other producer using small quantities of steam; but the gas made in the Maclaurin producer when working for coke differs from anything which has been offered to the Ceramic Industry hitherto. What the Ceramic Industry has been looking for is a gas which would give a reasonably long flame at a reasonably low price. The only place from which such a gas might have been obtainable would have been the surplus gas from coke ovens.

The gas from a Maclaurin producer working for coke meets the potters' requirements admirably. We have seen that gas made in the plant is a mixture of water gas, producer gas, and distillation gases. When running to ash the proportion of distillation gases to water gas and producer gas is naturally small, but when running for coke the proportion of distillation gases is quite considerable. The analysis and calorific value of the gas made under such conditions indicate this very clearly. In the first place, the calorific value of the gas is round about 240 to 250 B.Th.U. per cu. foot. One advantage of this is that its distribution for considerable distances becomes a reasonable proposition. A typical analysis of an average sample of the gas made during 24 hours is as under :—

CO_2	C_nH_{2n}	O_2	CO —	CH_4	H_2	N_2
6·2	nil	0·6	16·0	13·0	16·1	48·1

The calorific value of this gas is 247 B.Th.U. gross. You will

notice from the accompanying table how this gas differs from the gases we have been considering.

	H_2	CO	CH_4	CO_2	N_2	O_2
Gas from Maclaurin Producer ..	16·1	16·0	13·0	6·2	48·1	0·6
Coke-Air Gas Producer	4·0	32·3	0·8	1·6	61·3	
Duff Producer ..	13·4	26·8	4·4	4·0	51·4	
Duff Recovery Producer ..	28·0	11·0	2·5	15·5	43·0	

The points to remember are:—Hydrogen by itself gives a short, fierce flame. CO gives a medium length of flame, but is easily extinguished. CH_4 gives a flame of considerable length. The coke air gas is, therefore, too readily extinguished. The Duff recovery gas will give too short a flame. The Duff non-recovery gas is the best of the three, being somewhat similar in analysis to the gas made in a Maclaurin producer working for complete gasification and with recovery of bye-products, but the high percentage of methane in the gas made in the Maclaurin producer when working for coke puts it in a category by itself. The desirability of methane and hydrocarbons in the gas is definitely recognised already by those employing gas for firing, and they consequently use good bituminous coal for their producers in place of coke, even though this has the effect of tarring and sticking the valves, and giving trouble in the flues, and giving gas of a less uniform quality. Owing to the great height of the Maclaurin plant, the hourly addition of 1 ton of coal makes little difference in the calorific value of the gas, whereas in shallow producers each addition of coal is followed by an enrichment of the gas passing to the kilns.

It is not my province to criticise seriously the methods of firing at present in vogue in many establishments, for most of you will be more familiar than I am with the wastefulness of many of the kilns now in use; nor is it my province to endeavour to prove to you the economy involved in gas firing when compared with coal firing. I have seen a continuous brick kiln fired with coal, and a continuous brick kiln fired with gas, and am of the opinion that, heretofore, on the point of fuel costs, there could not be any very large saving in favour of gas. It is the incidental advantages that probably weigh most in the favour of gas. For example, you cannot readily obtain scientifically trained men to wheel coal to fire doors, but you can employ scientific control, when gas taps are all that require adjusting. The freedom from ash in the brick chambers is also much in the favour of gas. When we turn from continuous kilns to the non-continuous kilns, the waste of fuel becomes glaring. Here scientific control is almost hopeless. You may see almost any day an able and conscientious fireman engaged in a rather hopeless struggle with the South West wind or with no wind at all. Flame is blowing out from half of his fire doors at

one moment, while at the next there is an inrush of air over the top of his fires, out of all proportion to what the gases from the coal require, and this sort of thing goes on continuously till the kilns get properly heated up. Now, let me suggest here in all humbleness of spirit, that gas delivered at the firedoors, even of old fashioned kilns, is a much better proposition than coal, and it is generally fairly good coal, wheeled in barrows to the same doors and from which later the ashes will have to be wheeled away. I submit that there is no difficulty in altering the fire doors to take gas, and as this gas can be driven in under pressure, drawing with it its actual requirements in air, the pottery burner becomes master of his fate.

To those who maintain that a smoky flame is essential, I would point out that the smoky flame, if it is essential, is only essential for a very short period of the firing, and to meet their views I would suggest, and it would possibly be a source of further economy, that there be left at each fire door, slightly beyond where the gas flame impinges, a small opening, which can be closed by a cover when not required, and that through this opening small quantities of duff or other cheap smoky fuel be dropped at such times as the smoky flame is thought to be desirable. The cost of changing the fire doors to suit would be negligible. I am not blaming the pottery owners for not making such changes. What has been offered, heretofore, by the gas plant manufacturers has been either a hot non-recovery producer gas at a rather high cost, which could not be readily handled in the way I suggest, or a clean cold recovery producer gas also at rather a high cost, but with a composition very unsuitable for the purpose required. The gas from the Maclaurin plant is clean, cold, of suitable composition, and producible at a lower price and, therefore, demands fresh consideration by the pottery owner's technical staff. From the nature of this gas and its high calorific value, its distribution to any part of the works is a very simple matter. There are other requirements in the potting industry where a cheap gas offers possibilities and I will now briefly refer to these before closing this somewhat rambling discourse.

Power is required for working up the clay and heat is required for drying the ware when in its green state. This heat is often provided by passing steam under the floors of the drying sheds. This steam, however, has to be obtained from coal and for this purpose the coal is burned on the boiler fires. This involves labour and under the very best conditions steam is seldom raised under 1/6 per 1,000 lbs. of steam, even in large power stations. One thousand pounds of steam contain approximately 10 therms, therefore the cost of 1 therm in this steam is round about 1·8d. per therm. We have seen that gas can be made available throughout the works at 1d. per therm and, therefore, it seems probable that much of the heating being done to-day by steam could be done

more economically by gas The gas might be burned in flues and the products of combustion could be driven or drawn through channels beneath the floors. Even supposing steam is preferred; with gas at 1d. per therm, it is possible by the use of gas-fired boilers to produce steam at a lower cost than by coal-fired boilers.

Power. There is also in every Pottery a considerable demand for power and the best means of obtaining this requires careful consideration., Steam is probably in most cases cheaper than electric power though not so handy. The gas engine, where gas can be obtained at a figure as low as 1d. per therm, will be difficult to beat so far as economy is concerned. With steam costing 1/6 per 1,000 lbs. to produce, a horse power hour will cost ·45d.—when a reciprocating engine consuming 25 lbs. of steam per h.p. hour is in use. With a better engine, or with a turbine, the costs might be reduced to about one farthing per h.p. hour. With electric current at ¾d. per B.O.T. unit each h.p. hour will cost ·56d. or slightly over one halfpenny. With gas at 1d. per therm each h.p. hour will cost ·11d. or only a trifle over one tenth of a penny.

Power generated by gas will, therefore, cost less than one half of what it will cost when generated by steam or electric current.

I might here suggest that the gas engine exhaust might be usefully employed by passing it under the floors of the drying sheds.

In concluding, let me point out that if the Potteries adopt gas firing on a large scale as here suggested, they will have done something to remove the bad name that has gathered round them as producers of smoke; and the public, even in their own district, will begin to look upon them again with feelings of respect and even of admiration, as representatives of that ancient craft with which art has been so long associated.

DISCUSSION.

Mr. Gill:—As a gas engineer, I have been very fascinated by the process which Mr. Maclaurin has explained to us. There is no doubt that this process has considerable scope in many directions; in fact, it looks to me as though it is one of the things that is really wanted. Mr. Maclaurin explained lucidly what really happens in a gas retort. There is just one small point about the horizontal retort that I might mention, and that is this: Mr. Maclaurin has depicted in his diagram a horizontal retort with a smaller charge than is generally employed. Some 15 years ago it became the best practice to fill horizontal retorts very much more than Mr. Maclaurin has indicated, in order to do away as much as possible with the splitting up of the gas as evolved from the coal by the high temperature at the top of the retort. This has brought about a great change both in the gas and the products distilled from the coal. The process that Mr. Maclaurin has described seems to be delightfully simple, but I should have

expected, as he said, that there would be great trouble with the caking mass of coal at the top. If Mr. Maclaurin has really got over these difficulties so that the gas and the liquid products can get out without causing a choking mass, I think he has achieved a very great thing. I do not want to criticise the paper at all, because it seems to me that it is one of those things which really deserves every encouragement. The process that Mr. Maclaurin has evolved should, I think, go a long way towards getting rid of the smoke nuisance, and for this reason I wish it every possible success. I have pleasure in proposing a hearty vote of thanks to Mr. Maclaurin for his paper.

Sir Wm. Jones:—I welcome the opportunity of seconding this vote of thanks to Mr. Maclaurin, and I agree with the remarks of Mr. Gill, that the paper has been a fascinating one, and that Mr. Maclaurin deserves every encouragement to go on with the development of this producer which bears his name, and which would appear to hold such great prospects of ultimate success.

There are certain points in the construction which Mr. Maclaurin has described which I should have been inclined to suppose would have created difficulties. Mr. Gill has referred to what he would have regarded as almost a certainty of trouble, arising from the condensation of the volatiles in the zone which is within the outer bell where the draining of the oils is allowed to take place. I am surprised to hear that there is no trouble at all in what I should have thought would have been a sticky, pasty, tarry mass of coal, even when large coal is used such as Mr. Maclaurin says he has resorted to in the working of this producer.

One other point of weakness I should have thought would have been the cross walls in that zone where the air blast is introduced into the generator. I should have thought, for instance, that one was resorting to total gasification by blowing in 80,000 cubic feet of air per hour per producer. I should have thought that the temperature of the firebrick cross wall would have been raised to such a height as to have led to considerable trouble. I should be interested to hear how long this producer has been working continually at Grangemouth without having been let down from the time it was started.

The yield of coke, oils and gas, from the figures which the author has given to us to-day, seems to provide great encouragement for the adoption of this producer where it can be worked continuously, and the gas can be utilised throughout the whole period. I judge from Mr. Maclaurin's paper that he only claims that an economical thermal balance sheet can be shown where large units are employed. He speaks of 10 units each of 20 tons capacity per day. Well, that is a very big plant, and it limits to a great extent the application of this producer if it is not possible to show an economical balance sheet with a smaller installation.

One thing occurred to me whilst I sat listening to Mr. Maclaurin, and that was this: I believe that if all he claims for this producer can be realised, and if the difficulties which one would have contemplated, to some of which reference has already been made, have been overcome, and this producer can be worked without trouble and satisfactorily for a long period, then there is a very great field for this producer not in this country alone, but more particularly in the Western part of Canada, because there there is much greater margin offered in working. I was in British Columbia some little time ago, and there in the Crow's Nest pass you have 14 per cent. of the world's coal, which, for the most part, is a coking coal, with an ash content of something varying from 9-12 per cent. But they are desperately short of fuel in the sense that throughout the whole of Western Canada the population has accustomed itself to the use of anthracite coal—a smokeless coal used for central heating purposes. Having, as they do have in these parts, very severe winters, they have need of such a fuel. They could almost blow away the gas to waste if they could produce from their own coal a smokeless fuel which will take the place of anthracite, which is becoming more and more scarce, and dearer and dearer. When I was over there anthracite was being purchased from Pennsylvania by the West Canadian settlers, and they were paying something like 22 dollars per ton for it, the bulk of which amount went in freight, the haulage necessary being from 2,500 to 3,000 miles. Now if the coal at their doors could be utilised in a producer of this character, from which a smokeless fuel could be obtained, and produce at the same time sulphate of ammonia, which is badly needed for the great wheat veldt, and oil in addition, it seems to me that this producer should be the very thing that the Canadian Government would welcome. I throw that out as a suggestion to Mr. Maclaurin. If he could get someone who would have the courage to put up one of these producers in the region of the West Canadian coalfield, and it will do all that he claims it will, Mr. Maclaurin has a wonderful field there, and he would not have to thrash his horse half so much as he would probably have to do with, say, the potters of North Staffordshire.

Mr. S. R. Hind:—I should like to support this vote of thanks, and in doing so I should like to say that whilst admiring the great ingenuity which Mr. Maclaurin has showh in devising this producer, I was struck very much with one point, and that is in connection with its use for pottery purposes. Mr. Maclaurin suggested that the gas might be substituted for producer gas as at present used. I gathered that this was what he meant or it might be that he believed it could be used in place of coal. But there is one feature in that producer which worries me very much. You get the gas all right, but at the same time you get a great deal of coke—a smokeless fuel, apparently, which is suitable for household purposes or for use as a metallurgical fuel. In any case that coke

amounts to a very considerable total From what Mr. Maclaurin has put on the board, his gas, at 77 therms, represents approximately 30 per cent. of the total heat value of the fuel put into the producer. In that case, with a plant in the Potteries which now requires 10 tons of fuel per day, it would mean that 20 tons of this coke has got to be disposed of in the works every day. Such coke, I think, will be generally considered to be unsuitable for burning in the boilers for steam production, and consequently, under present conditions, it would be necessary to make a new market for this fuel in the district. I think that is a point which the potters, and possibly the brickmakers also, would be rather chary of tackling.

The difficulty I see is that, if the Maclaurin Producer is to be introduced for Ceramic purposes, it must be effective as a single unit. In this case, the tars are not going to be recovered: complete gasification would give a fairly normal producer-gas with no apparent advantage over ordinary gas producers; so the typical smokeless fuel-process would probably be adopted. How then is a pottery or brickworks to dispose of say 20 tons a day of smokeless fuel at a sufficient profit to make the new adventure worth while?

Mr. Maclaurin:—I thank you for your very encouraging remarks.

In reply to Sir William Jones, I would like to say that we have never run the plant continuously for a long period, but it has already put through several thousand tons of material. With regard to choking at the condensing chamber, I experienced the same fear as Sir William Jones expresses, and provided mechanical means to clear away any choke which might occur, but after the plant had been run for about a year, we found that the mechanism had not been used, and consequently, when we came to erect our next plant, we put in no mechanism for this purpose and yet we have had no trouble at all.

Sir William Jones' remarks with regard to Canada are very interesting and helpful. After hearing his glowing account of the possibilities of Western Canada, I may have to consider going out there instead of trying to interest the manufacturers of the home Potteries.

In reply to Mr. Hind, I do not think there would be any difficulty in disposing of the coke. I do not think it would be advisable for the potter to put down a plant where he has to put two or three times the amount of coal through and sell the coke. I should rather be inclined to think that the reasonable thing is for a company to put down the plant and sell the gas to the pottery manufacturers and the coke to other fuel users.

X.—Contribution to the Better Knowledge of Genuine Hard Porcelain.*

By K. H. Reichau, D.Ph.
(Translation by F.S.)

OF recent years several references have been made by competent writers[1] to the numerous possibilities of applying the mineralogical microscope to practical uses. Nevertheless, this instrument has hitherto gained admittance into the laboratories of large industrial concerns only in isolated instances and with much greater difficulty than, for example, the metallographical microscope. Yet it is reasonable to assume that, in the near future, the mineralogical microscope will be assured of a leading position in the silicate industry, particularly in the fine ceramic, and, above all, in the porcelain branch, just as the metallographical microscope has, to-day, become an indispensable adjunct to the metal industry as a whole.

The microscope has already been applied repeatedly to the investigation of silicate bodies and of porcelains. In recent times its aid in the examination of clays and porcelains has been invoked by Hussak[2], Vernadsky[3], Glasenapp[4], Plenske[5] and Zöllner[6] in particular. In comparison with the results obtained by purely chemical means, the data educed by the aid of the microscope were relegated to a position of such subsidiary importance, that Steger[7] could write: "Only in exceptional cases are ceramic products subjected to thorough mineral-optical tests." However, when Rieke and Gary[8], at the request of the German Society for Testing Technical Materials, developed, for the first time, a satisfactory method of testing porcelain, they came to the conclusion, after comparing the results of such tests on commercial porcelains with data obtained by examining the same products in thin section under the mineralogical microscope, that it might even be possible, after a further development of the mineral-optical method of testing, to obtain full information as to the quality and properties of a porcelain merely by a careful examination of the material in thin section.

It may be of interest, therefore, to review the methods and results of mineral-optical tests on technical porcelains, using a microscope specially constructed for this purpose by the firms of

*The author takes this opportunity of expressing his sincere thanks to Dr. Köhler, of the Zeiss Works, Jena, to whose skill he is indebted for the photographs accompanying this paper; and to the representatives of the Firm in Berlin, particularly to Messrs. Otto and Kahle for their interest and assistance in the work.

Zeiss, in Jena, and Winkel, in Göttingen; and also to determine whether, and to what extent, such results could be attained by any method other than the purely optical one. In addition to a few porcelains, which were fired specially for the purpose, the electro-technical porcelains, including those employed in the manufacture of Hewlett insulators, were considered particularly suitable, for various reasons, for these investigations. This latter type of insulator, which is extensively used, is technically by no means easy to make, since it consists of sections composed both of thick and thin porcelain bodies. Furthermore, the German Electro-Technical Society has issued special detailed instructions, based on a wide practical experience, for testing the Hewlett type of insulator[9]. These recommendations, if properly interpreted as a whole, go to the very heart of what is exclusively a fine-ceramic problem. They prescribe not only that the finished insulator shall have a satisfactory external appearance, but that there must also be a perfect union of body and glaze; and further, that the body must be thoroughly dense, that the finished article must be sufficiently strong, both mechanically and electrically, and must be resistant to sudden (though restricted) changes of temperature. In the last-named test, which is known as the "heat-test," the finished piece is immersed alternately, three times, in cold (15°C.) and warm (75°C.) water, and is allowed to remain in the water sufficiently long to ensure that the whole body is warmed through, or cooled down. This "heat test", in conjunction with the demand for an absolutely non-porous body, represents the "experimentum crucis" for the value of a high-tension insulator. The more resistant a porcelain to this combined test, the better will it automatically satisfy the mechanical and electrical strength-test.

Several commercial Hewlett suspension insulators of 220 mm. diameter, supplied by two different works *A* and *B*, successfully withstood the piece-tests. Tests on the two materials indicated that the mechanical breaking stress for quality *A* was, on the average, 9 per cent. higher than for quality *B*, and that, under identical conditions, the electrical break-down strength in oil, at 100 cycles per second, was greater by 12 per cent., on an average, in the case of *A* as compared with *B*. In the "heat-test," quality *A* withstood permanently a temperature change of 90°C. (alternate immersion in boiling water and water at 10°C.), whilst quality *B* collapsed repeatedly on the first treatment at a temperature range of 45° (from water at 60° to water at 15°). On breaking with the hammer, material *A* proved to be tough and showed a conchoidal fracture, while *B* was brittle and broke like glass. A solution of fuchsin in alcohol showed no tendency whatever to "run" on the fractured surface of *A*; a thick stroke drawn across the surface with a pen exhibited, when dry, a clearly-defined outline.. On the fractured surface of *B*, on the other hand, the fuchsin solution "ran" as on sandstone, without, however, penetrating into the body of the

material to any visible extent. After the heat-test, the glaze on material *B* tended to craze, especially in the small grooves, in which a thicker layer of glaze had collected in the glost oven, the crazing being only visible on being magnified fifteen times. The glaze on body *A* remained quite intact, even after repeated heat-tests.

The chemical analyses gave :—

Mat.	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O K_2O	Total	Melting point
A	0·10	71·40	27·58	0·75	0·35	0·06	2·22	102·46	1690°C.
B	0·22	75·64	22·63	0·68	0·63	0·06	2·61	102·47	1670°C.

These analyses justify the conclusion, in explanation of the results of the above tests, that material *B* is richer in fusible quartz-felspar ingredients than *A*, owing to its higher alkali, and lower alumina content. Accordingly it should, as actually found by experiment, melt at a lower temperature than material *A*. This excess of fusible ingredients in *B* as compared with *A*, would also explain its great sensitiveness to sudden changes in temperature. On the other hand, contrary to the result of the fuchsin solution test, the fractured surface of material *B* ought to have appeared more dense than that of *A*. The result of the glaze test warranted the conclusion, that the glaze on material *B* was less suitable to the body, as regards its maturing temperature, than in the case of material *A*, although both glazes were adjusted sufficiently well to their respective bodies in respect of their coefficients of expansion.

The real explanation of the extraordinary superiority of

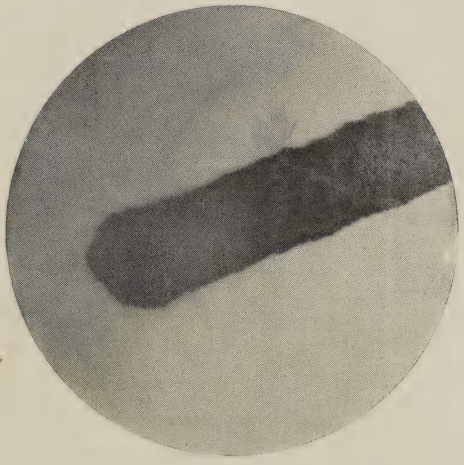


Fig. 1.
Porcelain A.
Showing ink mark on fractured surface, Vertical illumination. (×20).

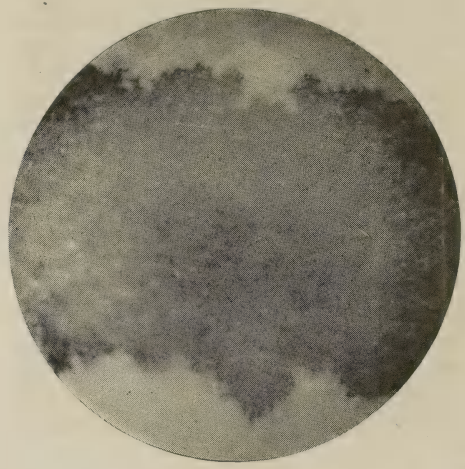


Fig. 2.
Porcelain B.
Showing ink mark on fractured surface. Vertical illumination (×20)

material *A* over material *B* is, therefore, not forthcoming from the results of these physical and chemical tests. Similarly, neither by physical tests nor chemical analysis is it possible to discover the reason why one high-speed steel is better than another. Yet, just as in the case of a steel, the metallographical microscope discloses the internal structure—and hence the reason for its superiority or otherwise—so the mineralogical microscope will, in the same manner, provide the explanation in the case of porcelains and glasses.

Figures 1 and 2 are photographs of the fractured surfaces of materials *A* and *B*, magnified 20 times and with vertical illumination. Both pieces were treated in exactly the same way. Immediately after breaking the piece, an ink mark, about 0·7 mm. thick, was made on the fractured surface, by means of a blunt pen. Sufficient ink was applied in both cases to allow for the possibility of the ink "running" on the surface, or of being absorbed by the body. Both pieces, *A* and *B*, were then left until the ink was thoroughly dry. The illustrations show the outlines of the ink marks on the fractured surfaces. It can easily be seen that the ink has "run" at the edges on both bodies (though to a much greater extent on body *B* than on body *A*), thus giving the impression that both bodies were porous in the ceramic sense. Nevertheless, independent tests for real and apparent porosity, carried out on the same bodies by other experimenters according to the methods described by Kallauner, Barta and Simane[10], showed conclusively that neither body *A* nor body *B* was porous to any measureable degree.

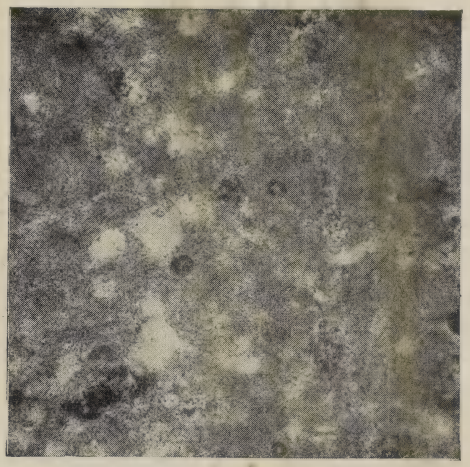


Fig. 3.
Porcelain A.

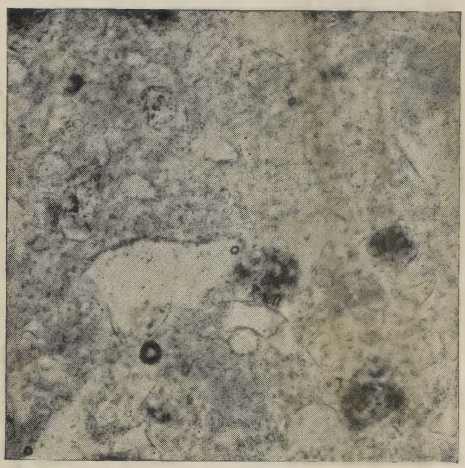


Fig. 4.
Porcelain B.
Thin sections in natural, yellow light (×250).

Figures 3 and 4 are photographic reproductions of materials *A* and *B* in thin sections, with magnification 250, taken in natural yellow light (layer, 5 cm. thick, of saturated potassium bichromate solution) on an ortho-chromatic plate, with an 8-mm. Zeiss apo-

chromatic lens, numerical aperture 0·65, and "Homal I."* These illustrations show very remarkable differences in the internal structure of the materials. Figure 3 shows only a few clear glassy areas on a background of a felted, crystalline material. These glassy areas, the edges of which are not easily discriminated, also enclose crystals which extend from the boundaries towards the centre. Body *B* (Fig. 4) exhibits no such tendency to the formation of a homogeneous, crystalline groundmass of this nature; on the contrary, it contains a large number of angular rock fragments, which are grouped together in an incoherent manner and among which the sharp outlines of many individual grains of raw material as used in making up the body are plainly visible. These separate grains are by no means of the same material, as microscopic determination of the refractive index by the Becke method[11] clearly shows.

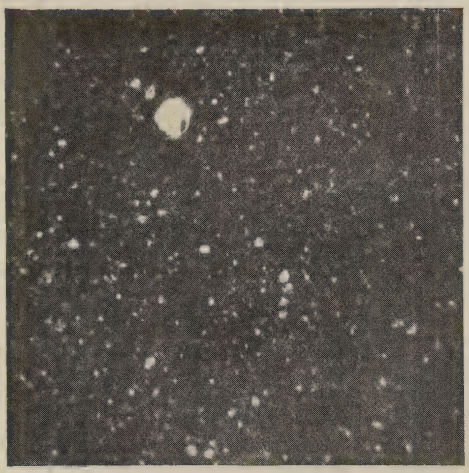


Fig. 5.
Porcelain A.

Figures 5 and 6 are photographic reproductions of the two bodies in thin section, magnified 30 times, and taken in filtered, circularly polarised light according to Dr. Köhler's method, which is described as follows:—"A quarter-wave mica plate was inserted above the Nicol prism serving as a polariser; this mica plate was so fixed that the axis of the index ellipsoid was inclined at an angle of 45° to the vibration plane of the polariser. A similar plate was placed at 90° to this frame above the objective. By this arrangement, practically all the undissolved quartz grains in the body

* A combination of lenses, placed near the eye-piece, to counteract errors due to aberration dispersion, etc., and to give a flatter field.

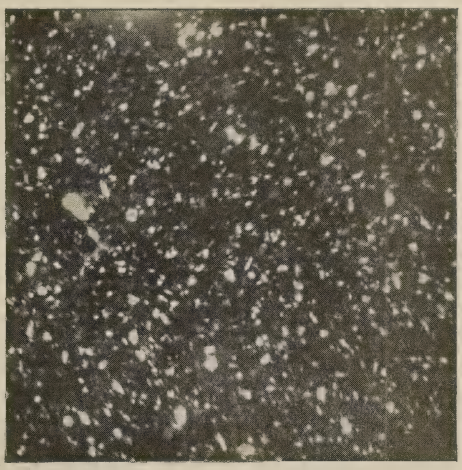


Fig. 6.
Porcelain B.

appeared more or less clear against a dark background, unless they happened to be vertical to the axis or had caused a phase-difference equal to one wave-length, which was highly improbable in a section of this thickness."[12]

The tremendous difference in the quantity of undissolved quartz in the bodies *A* and *B* becomes evident at once from a glance at the two illustrations. Furthermore, the grains of free quartz differ both in character and size in the two figures. In thin section *A*, they are more or less round in shape, and rarely exceed about 0·05 mm. in diameter, whereas in *B* they are angular, and frequently attain a diameter of 0·125 mm. and over.

By any other than the mineral-optical method, it would have been impossible to gain such insight into the structure of these bodies as is provided by the above six illustrations. Furthermore, the data obtained by this method fully explain the results of the practical tests mentioned above. Material *A*, which is by far the more homogeneous porcelain of the two, would naturally be expected to exhibit a marked superiority under the heat-test, since its structure would tend to facilitate the uniform distribution of heat throughout the mass, when the piece was subjected to rapid changes of temperature. In mechanical strength also, material *A* will show up to advantage, again owing to the structural nature of the body, while, in view of its marked crystalline character, its dielectric strength will be greater in accordance with the Maxwell theory; for, in passing through material *A*, the electric current

will meet, in all parts of the piece, portions which differ in the ratio of dielectric constant to conductivity. The result of these mineraloptical tests, indicates that material *A* could be employed with much greater confidence for the manufacture of electric insulators. The fact that the quartz, with its well-known chemical elasticity, is practically all dissolved, offers a much better guarantee that an insulator made from material *A* will resist in practice the disintegrating influence of all kinds of mechanical, thermal, electrical, and also, without doubt, internal chemical forces much more successfully than a piece made from *B*. This knowledge of the internal structure of a high-tension insulator will also assist in answering—presumably in the affirmative—the much discussed question of the ageing or decaying of porcelain, and will provide an explanation of the causes of the hitherto inexplicable breakdowns which so often occur in practice.

A few words of a purely chemical nature may here be added. It would have been simple either to have worked out the corresponding Seger formulæ, or to have calculated the rational analyses from the complete chemical analyses of the fired porcelains *A* and *B*. Such calculations, frequently made with the object of imitating certain porcelains, are quite useless. They do not take into account such factors as the physical conditions under which the raw bodies are built up, the behaviour of the various types of felspars when fired to high temperatures, nor the character of the clay substance, which varies so considerably in different kaolins. For example, the Halle deposit, which is of comparatively simple formation, and which has been subjected to a thorough geological investigation, exhibits at least three distinct types of kaolins, each of which is distinguishable by the peculiar nature of its clay substance. These specific types of kaolin are closely related genetically to the original rocks from which they were derived ; and similar rules hold good in other deposits, *e.g.*, the Meissen and Silesian deposits. Furthermore, the percentage of alkalies in the raw bodies invariably appears to be higher than in the fired product, indicating that the alkali in the unstable felspars volatilises more or less in the kiln; and this mobility of the alkalis appears to bear a definite and direct relationship to the utility of a felspar from the ceramic point of view. This uncertainty in the determination of the alkalies—and therefrom the felspar content—in the raw body, renders such formulæ particularly unreliable. Precise information as to the felspar content of a raw body is of paramount importance to the colour of the fired product. A body made from a grey-burning clay, and containing little felspar, will, on leaving the kiln, be quite discoloured by the natural firing-colour of the clay ; but such a body can readily be converted into a white-firing porcelain by the addition of only a small percentage of felspar, without in any way affecting the firing process, except in lowering to a very slight extent the maturing temperature. And since it is equally as simple,

and indeed of common occurrence, to produce, through faulty burning, a discoloured porcelain from a perfectly satisfactory body, it is obvious that calculations such as those suggested above must lose still more in importance when it is remembered that every body has to be fired according to its own particular schedule. A very simple test, the importance of which rarely receives the attention it deserves, namely, the firing in an oxidising atmosphere of a small cone, prepared from the material to be tested, will demonstrate clearly how various are the demands made by a ceramic body, by virtue of the more or less unstable metal silicates which it contains, upon the skill and reliability of the fireman.

A few remarks of a practical nature may not be out of place here. Experienced foremen in the porcelain industry are accustomed to judge the value of a raw body submitted to them for a works test, by testing whether the body is sufficiently plastic to be worked up, whether it stretches sufficiently in turning, whether it shows any tendency to separate out when made up into a casting slip, whether it dries rapidly enough and without excessive shrinkage, even when used in pieces composed of sections varying greatly in thickness, and finally, whether it can be fired without great difficulty to a dense, white porcelain and withstand the highest temperature of the kiln. It is, of course, well known that a compromise is necessary if all these demands are to be met. It is a simple matter to prepare two bodies, identical in rational analysis and physical composition, one of which would be highly plastic and produce a hopelessly bad porcelain, while the other, though extremely "short," would give a product of excellent quality. It is also a well-known fact, and one which has been proved by many failures in practice, that an attempt to apply the more or less empirical methods and experiences, which have proved satisfactory in the manufacture of thin ware in the table and art porcelain branches, to the preparation of thick pieces such as are characteristic of the insulator industry, offers little prospect of success. A body may prove quite satisfactory for making small cylinders measuring 1 cm. in diameter and 4 cm. in height and may give a pure white and dense fired product ; yet the same body would in most cases prove altogether unsuitable for making cylinders of the same height, but of 4 cm. diameter. It is not clear whether all these points of view received attention by Rieke[13] in his admirable work : "On the effect of the grain-size of the non-plastic material on the behaviour of fine ceramic bodies in firing," since only those changes which take place during the firing operation are described by him. If due consideration is given to all the factors which came into operation in the production of porcelain *A*, it will be seen that it would be impossible to remove entirely all traces of the free quartz in the material by prolonging either the grinding of the raw materials or the firing of the ware. Nevertheless, the nature of porcelain A, which was not originally intended as an insulator

porcelain, can be varied so as to increase considerably its dielectric strength at the expense of its unnecessarily high resistance to the heat test, without materially affecting the mechanical strength. This could be done by suitably rearranging the body constituents within the ceramic three-phase system, clay-substance—quartz—felspar. Such a porcelain, in which the felspar content of the raw body would be as low as possible, and the quartz-content as high as possible, while the material providing the necessary clay-substance would have to be selected with the greatest care, could be prepared entirely from German materials with the exception of the felspar. The body would have a rational composition corresponding to 47 per cent. clay-substance, 35 per cent. quartz and 18 per cent. felspar, and would be highly plastic and suitable for casting in slip form. In thin section, this porcelain would be found to have lost completely its clastic structure and would appear as a homogeneous mass, closely knit together by sillimanite crystals, and showing only traces of free quartz.

It now remains to be shown whether, and to what extent, the mineralogical microscope is capable of disclosing the internal

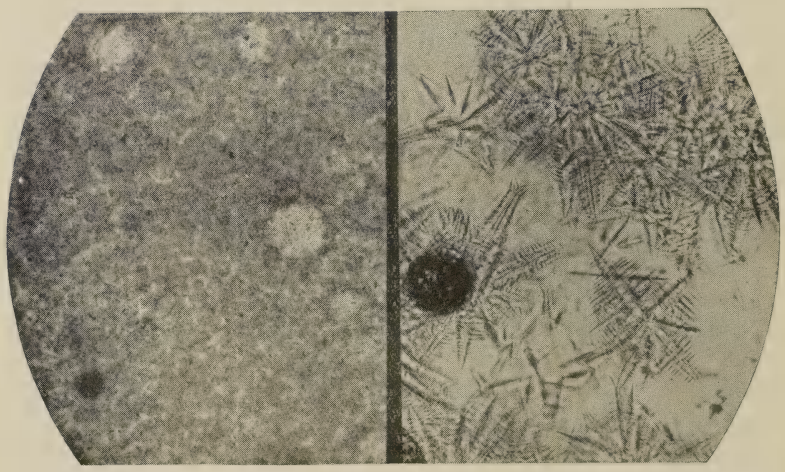


Fig. 7.
Glaze on Porcelain A.
Entirely microcystalline.

Fig. 8.
Glaze on Porcelain B.
Highly devitrified.

structure, and hence the value, of a porcelain glaze.

Figures 7 and 8 are reproductions of the microphotographs of the glazes on porcelains *A* and *B*, taken with a Zeiss 8-mm. apochromatic lens, numerical aperture 0·65, "Homal" I. magnified 250 times. It is obvious at first glance that glaze *A* is a genuine microcrystalline hard glaze, whilst glaze *B* is highly devitrified.

This result explains at once the difference in the behaviour of the two glazes under the heat-test, and further, it demonstrates clearly that the glaze on porcelain B is of faulty composition. Neither the chemical analysis of the glaze ingredients, the rational analysis of the prepared glaze, nor the corresponding Seger formulæ could furnish this information on the structure of these glazes. The Seger formulæ of glaze *A* is here given merely to indicate the type:

$$\left.\begin{array}{l} 0{\cdot}11\ K_2O \\ 0{\cdot}67\ CaO \\ 0{\cdot}22\ MgO \end{array}\right\} 1\ Al_2O_3 : 10\ SiO_2\ ;\ i.e.,\ 1\ RO : 1\ Al_2O_3 : 10\ SiO_2$$

These optical results also explain why glaze *B* could hardly be considered as providing the necessary protection to the insulator against the weather and against chemical action. The coefficient of expansion of the crystals embedded in this glaze differs from that of the amorphous portions, so that stresses are set up within the glaze by changes in temperature. In time, these internal stresses lead to crazing of the glaze and also to the creation of stresses in the body. These inner molecular rearrangements, with the consequent internal stresses, are well-known in the glass industry; in the end, portions break away from the main piece, or, in the case of thick glasses, the whole piece collapses, the stresses being in this way relieved. Partially devitrified glazes of this type tend to facilitate the collection of dirt on the surface of the insulator as a result of crazing, and, in consequence, the danger of leakages to earth is increased. After a time, the surface of the porcelain becomes rough and unsightly, and, instead of protecting the insulator, these glazes are themselves frequently the original cause of serious defects.

In the above notes, only a few of the more important possibilities of the application of the Zeiss-Winkel "ceramic microscope" are indicated, the methods and results, of interest both to manufacturers and to users, being illustrated by a comparison of two commercial porcelains. The data provided by this instrument in disclosing the nature of the internal structure of the two porcelains clearly demonstrate the marked superiority of quality *A* over quality *B*; furthermore, the reasons for this superiority are also brought out convincingly—with the same elementary precision, in fact, as is possible in the case of metals and alloys by the aid of the metallographical microscope. Moreover, it has also been shown that the ceramic microscope is the only instrument by means of which it is possible to compare, in an objective manner, the true value and reliability of two ceramic products. It may, therefore be assumed that, in future, both the maker and the user of the better qualities of porcelain will make use of the microscopical test in thin section, a test which, at present, is looked upon more or less as a curiosity. This applies with special force to high-tension technique, which, with its ever increasing transmission voltages, is constantly making higher demands upon the quality

of the porcelain. But it also concerns the ceramic industry, which, as a branch of the chemical industry, should endeavour to gain as full a knowledge as possible of its raw materials and of the varying reactions of one material upon another in the manufacturing processes, in order that the best possible ware may be produced in the most rational way. The wretched empiricism so often met with on high-tension porcelain works, with the inevitable losses associated with it, must exhaust prematurely the by no means unlimited supply of high-grade ceramic materials in Germany, and will shake the confidence of capital in the stability of a technique which is undoubtedly capable of high development. And this development will begin to be realised when a conscious effort is made to apply the law of mass action to the reactions taking place in the chemistry of the silicates.

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XI.—Improperly Pugged Clay and its Effect on :—

(*a*) **The wage earning capacity of the operatives;**

(*b*) **The loss by defective ware to the employers.**

By Arthur Hollins.

IN the first place, I think I ought to state how it came about that I am here addressing you. As no doubt you are aware there is in existence the National Council of the Pottery Industry, composed of equal representatives of employers and operatives. At the Quarterly meeting of the Council, held on 11th October, 1923, the question of the trials of the operatives from improperly pugged clay was raised by one of the workers' representatives and sone discussion ensued, when the matter was referred to the Research, Inventions and Designs Committee of the Council, at which Dr. Mellor and Mr. Bernard Moore were present, when a very interesting and educational discussion took place. Following this meeting, Dr. Mellor wrote to my Society, the "National Society of Pottery Workers," urging that it should be responsible for giving a paper on the subject.

My Society readily consented and requested me to undertake the responsibility of giving the paper, but promising at the same time to give every assistance in supplying me with information bearing on the subject. I am indebted to Dr. Mellor for lending me his copy of the Transactions, 1908-9, in which appears the paper on "Pug Mills," by Mr. F. Lane, to which I shall make reference, as also to Bourry. It is not intended to discuss the various types of pug mills, as these have already been thoroughly treated in the paper given by Mr. Lane, but it is rather to call your attention to the obvious which is too often overlooked.

There is just one point to be made with regard to the vertical pug mill, and about which there is some difference of opinion amongst the operatives as to whether or not it is to be preferred to the horizontal. Bourry states that "when it is desired to obtain bodies of greater consistency it is preferable to use horizontal pug mills," thus, in effect, with the exception of the China trade to which reference will be made later, giving support to the horizontal pug mill. Vertical pug mills are built on the same principle as horizontal and the only advantage of the vertical is the saving of motive power on account of the weight of clay assisting its own passage through the pug mill. There are, however, the following disadvantages :—

(*a*) Not so easy to feed, as the inlet where the clay body is introduced is necessarily very high above the floor level.

(*b*) The resultant clay body is not so consistent or homogeneous as in the horizontal.

(*c*) It is difficult to get a firm foundation such as can be obtained with horizontal mill.

One of my colleagues suggests that there may be some consideration given to the outlet of the pug mill, and a round aperture used instead of the square one, as the body of the mill, being cylindrical, the texture of the clay is altered through having to pass through a square aperture.

"Pug mills primarily give the necessary plastic homogeneity clay bodies require to fit them for the clay worker or machine. Secondarily, though of no less importance, they give the final mixing to the material when two or more clays form the body we have to work."

"Where clay requires an extra amount of pugging, the double shafted mill is worthy of your consideration." (*Vide* Lane).

Before leaving the question of pug mills, I want to call your attention to a form of pug mill which is in general use on the Con-

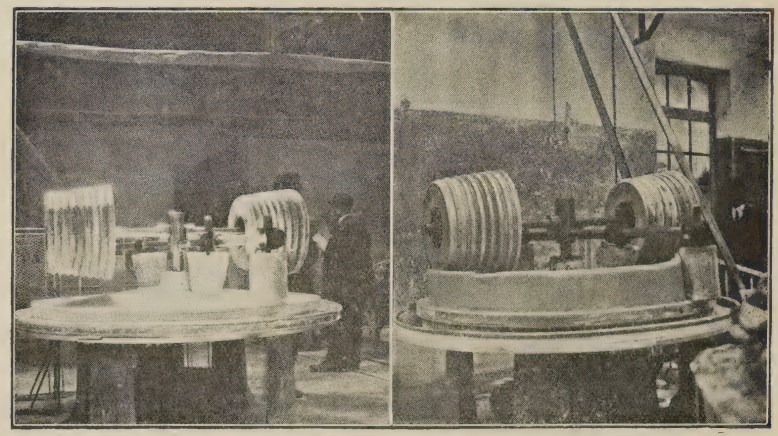


Fig. 1.

tinent, but has only been introduced at one firm in the Potteries. This method would not be practicable where the clay body is used in great quantities, such as in the large general earthenware factories, but certainly for china bodies rich in bone and china clay it is a most efficient method of pugging and gives a clay body very pleasing to the operatives. The following description is given, in his own words, by a Longton china thrower, who has worked the china body coming from this machine :—"The best pug for rendering the clay really consistent and homogeneous of which I know, is the one in use at Messrs. Shelley & Sons' Factory, and is an excellent and efficient machine. (Fig. 1). The clay is laid on a fixed round pan under a large roller and supported on either side of the mass

by two smaller ones running in opposite directions; these prevent the clay from being forced out of contact with the main roller which is continually travelling over the clay, which is occasionally turned over by the man in charge. You will, of course, observe that there are no knives to this machine, therefore, the clay is not chopped into consistency, but is rolled into it. It may be open to question as to whether this machine is capable of pugging clay of any density, but my own personal opinion is that it would. For the particular china body used at Messrs. Shelley's factory, it produces a clay of a nice, soft consistency, which is in excellent condition for the operative. There is no necessity for the pug operator to be constantly in attendance, as the clay body is put on the machine at once, and taken off after it has been running for about half an hour."

"Notwithstanding the compression in the pug mill, the bodies always contain a certain quantity of air bubbles, which occasion inconveniences in the formation, especially for fine and thin wares. In order to free the bodies from these, recourse must be made to a final operation, designated under the name of wedging. The latter is often done by hand, but for large productions, this long and laborious work is replaced by machines." (*Vide* Bourry).

The machines referred to are of the type described above. (Fig. 1).

During my visit to Germany last year, I saw a similar machine at work and tested some of the clay which appeared to be in perfect condition for manipulation. The test applied was the old fashioned one used by all potters, that of impressing their thumbs in the clay, and by the sense of touch, which is acquired by all workers in the clay processes and becomes almost instinctive, determining whether it is in a condition suitable to them.

I now come to the real subject matter of my paper and shall deal first with the effect of improperly pugged clay on the wage earning capacity of the worker. All workers in clay processes are employed at piece work rates which are calculated to produce a certain wage under the best conditions of work.

It is obvious that if any factor should fail to function properly, of which there are many to be contended with by the operative, the output of the worker is affected thereby, and his wage earning capacity reduced, The quality of the clay supplied, either in its consistency, plasticity, or homogeneity is not the least important factor. Without being too precise in the technical definitions of these terms, it will be necessary to give you some idea as to how the operatives would define them :—

(*a*) Consistency would be the same uniform hardness or softness of the clay throughout the mass.

(*b*) Plasticity would represent all the varying degrees of toughness from the very plastic body where ball clay is predominent, to the very short body in which china clay and flint predominate.

(*c*) Homogeneity is very closely allied to (*a*) but for the purposes of this paper also means the elimination of air bubbles.

Before dealing with the improperly pugged clay, there is a very important matter which should receive the attention of the clay managers, and that is the different quality of clay required by :

1. Hollow-ware Jolliers and Pressers, Large Ware Throwers.
2. Dishmakers.
3. Throwers (Small Ware).
4. Plate and Saucermakers.

The quality referred to cannot be produced by the most perfect system of pugging, but by the wise selection of the clay after leaving the presses. Taking the processes in the order stated, there should be a gradually increasing softness, but in a more marked degree so far as the plate and saucermakers are concerned. This question has raised more contention between the workers in the various processes and the head slipmaker than even badly pugged clay. Each department complains if the required quality is not delivered, and, of course, it is a natural complaint, as it seriously affects the earnings of the workers concerned. It is impossible for a hollow-ware jollier, dealing as he does with large masses of clay, to manipulate a softer clay such as would be suitable for a platemaker. In the first instance, where a spreader is used, the clay, if too soft, has a tendency to fly off the rotating plaster block. It is also difficult to raise the large bat of clay to the chum and to work it down the chum, previous to being placed in the mould. Where the bat is transferred direct to the mould, the clay has a tendency to break before it can be properly moulded.

This illustration is sufficient, without further elaboration, to indicate the necessity for better methods of selection of different qualities of clay bodies to suit the requirements of the operatives in the several processes, which would not only improve the wage earning of the workers, but would result in a better quality of work; further, it would prevent the constant friction between the slipmaker and the makers. Apart from the proper grading of the clay to suit the different processes, there are faults of pugging common to all, viz.:—

(*a*) Clay bodies may be either too hard or too soft for any branch of worker.

(*b*) There is too often a mixture of both hard and soft clay.

(*c*) Clay containing a large amount of confined air.

Any one of these faults seriously affects the earnings of the worker. In the first place, if clays are too soft, or too hard, it must of necessity affect the output, particularly when it is remembered that 4,800 to 8,400 plates, or 10,800 saucers must be produced to enable the maker to earn a week's wages. Every fraction of a second lost on each article amounts in the aggregate to an appreciable loss on the total output for the week. Secondly, a very serious loss in wages is due to faulty ware owing to the uneven contractions set up by

hard or soft clay bodies, in addition to the difficulties of manipulation, again decreasing the output. Thirdly, a clay body which is not homogeneous, free from confined air, is constantly a source of worry. The surface of the ware is covered with numerous blisters caused by the pressure of the profile bringing the confined air to the exposed surface of the ware. Much time is lost by the operatives in pricking these air bubbles, and in many cases they are so numerous that the clay has to be removed from the mould and a new start made.

If a case has been made out that "improperly pugged clay" or clay not suitable to the several processes, seriously affects output, an employer does not require to be told that, if the maximum output is not being reached, there is a certain amount of waste in motive power and machinery, and overhead costs are higher in proportion to the loss. So far as the "loss by defective ware to the employers" is concerned, it is a well-known fact that, even for ware in the clay state, they, the employers, have had to pay the workers for cracked and blistered ware owing to the bad condition of the clay supplied to the makers. Further, some of these faults do not appear until the ware has reached the biscuit warehouse in the form of cracked, crooked, or blistered ware.

It may seem far removed from the question of pugging, but many of the difficulties of the lithographers and transferrers in fitting patterns, which have been produced to fit a definite size, arise from the difference in contraction which takes place between orders made at different times from clays too soft or too hard or a mixture of hard and soft. It is an elementary principle that, if more or less water is contained in a body mixture, more or less contraction takes place in proportion to the amount of water driven off.

There is a serious loss of wages to the lithographers, printers and transferrers due to the difficulty in obtaining uniformity in the size of the articles to be decorated. Of course, the irregular firing of the ware may cause a variation in size apart from the faulty material. There is another serious loss to the employer—the effect of too soft a clay on the mould, thus causing a pin-holey surface which reduces its life.

Before proceeding to make suggestions as to the best methods to be adopted for ensuring the production of the most suitable quality of pugged clay, it will be necessary to consider for a moment or two the effectiveness of the pumps, filter presses, and press cloths. These should always be kept up to the highest state of efficiency, so that a more uniform state of the clay rolls from the presses may be obtained, as it must be very difficult for the man in charge of the pug mill to produce a satisfactory clay from the mill if he has to feed it with rolls which vary from very hard, to others which are very little removed from the slip state.

Summary and Some Suggestions.

Some of the points raised in Mr. Lane's paper are so important and meet the operatives' point of view, that they are well worth repeating:

"Much thought must be given to experiments made before being satisfied that the mill is fulfilling all which may be required of it. We must pug with the least amount of water the consistency required will allow and do this with least expenditure of motive power. The speed with which the clay travels through the pug mill is governed by the pitch of the blades, and the number of revolutions, and secondly, by the size of the delivery door. These factors should be proportioned to suit circumstances. Very often an increase or decrease in the number of revolutions per minute will give the desired effect to the homogeneity of the pugged material. A case in point:—Great trouble was experienced in getting a very fat clay out of the pug mill; the speed was reduced to 90 revolutions per minute, and was successful in overcoming the difficulty. With moist clays an increase in speed is desirable, and leading English pug mill makers are following the Continental makers by increasing the speed, thus obtaining in many cases, a better product and a decrease in motive power required. Worn knives, periodical examination. Case in point:—As much as an hour and a quarter has been required with worn knives, more than was necessary, in what should have been a day of eight working hours with good knives, besides having evils of improperly pugged clay accompanying, being a loss of 16 per cent. on labour and wear and tear."

Following on these suggestions as to the care and speed of the pug mill, it is essential to mention several other important factors which would tend to better results coming from the mill.

(*a*) It is too often the case that an inexperienced youth is given charge of the pug, instead of a man who understands the principles of the pug mill, and the quality of clay he has to produce; needless to say, such men can be obtained if a proper inducement is given in the form of reasonable wages.

(*b*) There is need for some reconstruction in the sliphouse, so as to provide for the storing of clay as it leaves the press, and also after it is pugged. Matured clay is always better for manipulation by the worker.

The pugged clay should be graded to suit the several branches of the trade and great care should be taken to protect it from draught and to maintain its consistency.

(*c*) There may be some difference of opinion as to the method of feeding the pug. My own view is that, given a pug mill of the generally accepted horizontal type and in perfect running order, it is a matter of indifference how the clay rolls are put in so long as the pug mill is kept full. Others incline to the view that the rolls should be placed in vertically.

(*d*) The pug mill should be kept full, otherwise, if partially full, air is apt to become confined in the clay and cause blistered ware.

(*e*) Reference has been made to the storing of the clay from the presses, in which case hard and soft clay rolls should be kept apart and the man in charge should blend these judiciously in the pug.

(*f*) No pug operator should be allowed to put water into the pug mill indiscriminately, as it is impossible to get a consistent mass by such a method. This statement only applies in the cases where the attendant puts in quantities of water at intervals, but where the water drops into the mouth of the pug mill from jets and in a steady stream, it may serve a useful purpose.

(*g*) Finally, and not the least important, is the need for better organisation in the sliphouse in the direction already indicated.

The workers, to be able to produce the best result, must be provided with the best material: if this is done all misunderstanding between the clay worker and slipmaker would be avoided, and it is in the interest of the firm generally to have a contented set of workpeople.

DISCUSSION.

Mr. Lane:—I have been deeply interested in the paper which has been read, and although the clay with which my experience of pugging has been connected is somewhat different from the finer clays of the domestic potters, yet the general principles have been comparatively the same. As regards the type of pug mill which depends upon the knives, the vertical pug mill is not so convenient as the horizontal, unless provision is made for it to be easily fed, but the vertical or inclined pug mills—some of them are placed at an angle of 60 degrees—take less power than the horizontal, and as regards the quality of the material produced, I think they can be made to vie very much with the horizontal. There is one point that Mr. Hollins has brought forward which strikes me as being very important, and to which very little attention has been given, generally speaking, and that is the maturing of the clay. You can have any amount of work put on to the clay by the machines, but unless the clay has been matured you do not get the results which ought to be obtained. I remember, on a visit to America, inspecting one works where they were producing glasshouse pots and tank blocks, and one of the great points at that particular works was that after the clay had been ground, mixed and pugged, it was stored for some days and then pugged over again. The clay was then cut up into clots which were put down into cellars, and no clay at all was used for the making of

glasshouse pots or tank blocks until it had been stored in those cellars in darkness and a humid atmosphere for at least nine months. It was remarkable the few breakages and failures that this firm experienced. This was attributed chiefly to the fact that the clay had been stored in this way. Now as regards the mixing of the clay, if you have taken any really deep interest in the subject, you will probably agree that the addition of water to the pugmill, which Mr. Hollins referred to, is calculated to be very disastrous. If you take a microscope and examine the clay, you will find fine globules of free water hanging in between the particles of clay, and that indicates that a very intimate mixing indeed is required. As regards the general remarks of Mr. Hollins, I think it has been emphasised that what you really require in every part of the works and in every operation is co-operation. It is no use at all one part of the work being properly done if another part is being neglected. The day has come when masters and men are being drawn nearer and still nearer together, and close co-operation between the two was never more desirable than it is to-day.

MAJOR. B. J. MOORE:—I have been very much interested in listening to Mr. Hollins' remarks, but I must confess to a feeling of disappointment, because I think he has departed from his real intention of giving us the benefit of his assistance in the production of better clay for hollow-ware jiggerers, jolliers, flat pressers and the like, by practically confining his remarks to pugging methods that are adapted for the mixing of grog and clay in the production of fireclay goods and saggar marls. It seems to me that it was rather a pity that he quoted extracts from Mr. Lane's paper on pug mills in support of practices which should be adopted in connection with the pugging of general earthenware and china, because, to anyone who has not studied Mr. Lane's paper, these extracts are apt to be somewhat misleading. Whilst it is true that Mr. Lane refers in his paper at some length to the general consideration of horizontal and vertical pug mills, it seems perfectly obvious to me that these remarks refer, generally speaking, to the mixing and pugging of fireclay bodies containing grog, which depend, partially or wholly, on the pug mill, whether of the pan type, commonly known in our district as a grog pan, or of the horizontal or vertical type similar to those used for the pugging of ordinary earthenware or china bodies. Further, I fear that I must dispute Mr. Hollins' suggested order for a gradually increasing softness in the condition of the clay, commencing with the hardest clay for the throwers. I should, undoubtedly, place the order as follows:—(1) throwers; (2) large-ware hollow-ware jiggerers; (3) dish makers and plate-makers; and lastly, small inside jolliers, such as cup-makers. For ware which is jollied inside the mould I think, undoubtedly, the clay can be used somewhat softer; but I can find no evidence at all to justify this in the case of plate-makers or saucer-makers. If the latter

were to use clay that is considerably softer than that which is used by the dish-makers, there is likely to be great difficulty experienced in the making of a dense plate, and the clay is apt to run off the mould.

There are other remarks of Mr. Hollins which I think are rather open to criticism. But I would like to ask him what he means when he states that some trouble in pugging was overcome when the revolutions were increased to 90 per minute. I have no knowledge of any china pug mill operating in the region of 90 revolutions per minute. I feel quite sure that, if Mr. Hollins will study Mr. Lane's paper more carefully, he will find that Mr. Lane was referring to some type of mixer, and not to a pugmill such as we have been discussing to-night.

I do not agree that it is better to store clay after it has been pugged. Unless it can be pugged again immediately before use my view is, that the sooner it can be used after pugging the better.

Far too much attention has, I think, been given to the question of pugging and too little to blunging, sifting and clay pressing. I am quite sure that a very large percentage of the faults that are usually attributed to faulty pugging are due not so much to direct errors in the pugging process itself as to bad blunging, the use of dirty water, faulty sifting, leaky pumps or inefficient press filling—these either singly or in combination.

Mr. Hollins:—I am somewhat staggered by Mr. Moore's statement that I have been dealing in my paper with such things as grog mills. In no portion of my paper has it been my wish to give you the slightest impression that I was dealing in any way with grog-mills. I said that I would keep away from the technical side so far as a description of the various types of pug mills were concerned, and the only words which I have culled from Mr. Lane's paper are those which seemed to fit in with the views of the operatives in regard to pug mills.

With regard to the speeds, I also disagree with Mr. Moore that these have only to do with fireclay or similar bodies, because, undoubtedly, Bourry also supports Mr. Lane's contention in regard to bodies such as we use generally in connection with the trade of this district.

Again, I have kept my paper, I hope, intensely practical from the operatives' point of view, rather than from the scientific experts' point of view. As to the number of revolutions at which the pug should work, all that I am endeavouring to do is to call attention to the fact that the speed of the pug should be regulated by the quality and amount of clay that is required to pass through the pug, and with such expert opinions behind me as Lane and Bourry, I feel that I am on right lines in asking you to consider the matter from this point of view.

I entirely disagree that in any part of this paper have I intended to refer to anything except the production of properly

pugged clay for the use of the earthenware and china trades. I mentioned at the beginning of my paper and again towards the latter end that, apart from the pugging of the clay, one must take into consideration the pumps, filterpresses and press-cloths, as a primary matter, before one can deal with the pug, so that I anticipated the criticism which has been levelled by Major Moore.

I agree with him to some extent in his suggested variation of the order of the softness of the clay so far as the hollow-ware jiggerers, dish-makers, throwers and plate-makers and saucer-makers are concerned; but in that matter I modified my suggestion by remarking that smallware throwers should be in the third position, and that large ware throwers would have to be placed in the first category. Possibly Major Moore's further modification might even be a better one than mine.

Mr. W. Shaw:—Since it was I who was responsible for bringing this matter to the notice of the National Council of the Pottery Industry, perhaps I might be permitted to say a few words. My idea of the matter is that you have got to have a pug which, when everybody else has practically made a mess of the clay, will put the thing right. Someone once wrote: "There is a Destiny that shapes our ends, rough hew them how we will." Well, I have come to the conclusion that a pug, from the point of view of the potter, has got to be that Destiny. When the matter came before the National Pottery Council I tried to build up the idea that the present pug mill only cuts the clay roll once, and fails to blend it, as practically only pressure is used. As regards grog mills, saggar marl, fireclay, pugs and the rest of it, I had a good many years' esperience of these, and I was considered at one time to be an expert, although I know that is not saying a great deal. Now, in an ordinary pug, you have got the blades all one size, and they are all set in one particular way, the idea being to create driving power. But there are three distinct processes, or there ought to be, in a potter's pug. I think a pug mill should be capable of performing three distinct and separate operations on the clay rolls, during their passage from the inlet to the outlet, if the highest possible results are to be attained. There is first the process of cutting the clay into fine shreds; secondly, there is a thorough blending of the shreds; and thirdly, the greatest amount of pressure should be applied immediately prior to the exit. It seems to me that the trouble amounts to this: the system of kniving is altogether wrong. What we want is a system whereby, when the clay comes into the main casing, a number of fingers on the shaft should proceed to cut the clay into as many fine shreds as possible. Then you want a certain length of the casing which is thicker than the rest, but with very little flange on, so that it will hold the clay and blend it. It must, of course, have a little flange in order to press the clay forward, but there should not be too much flange. And then when you get to the last part of the casing you can, of course, have your

knives as broad as possible in order to create that amount of pressure which is required to drive it out. If you were to devise a pug on that system, it is my firm belief that it would obviate many of the faults that the most inexperienced slip-maker can produce, and it would result in the production of a clay that is satisfactory to the maker.

But there is one other point that strikes me. I always found in my experience of mixing that some marls take a greater length of time to soak than others, and I have often thought—as workers, it is our business to think and not to speak—that in the slip-making they work on the system that the china clay and the ball clay and the various other materials all want about the same amount of knocking round and soaking. Well, I think the result of this is that we, as clay workers—I am a hollow-ware presser myself—are troubled with clay that breaks up. If you are making big basins or any big stuff, and you commence to pick it up, it won't act; it goes the wrong way. I firmly believe that if we had a proper pug things would be very much better. In the past the pugs that have been supplied to the potters have simply been pugs made by weight. There does not seem to have been very much brain power expended to ensure that the clay is properly mixed. It is one of those matters that are worthy of the very serious thought of the engineers of the district. They are the men who should get on the job, and for myself I am satisfied that they could give us something that would do the work efficiently.

Major B. J. Moore:—Our friend who has just spoken seems to have made one of the most practical suggestions towards the betterment of clay in general. I think we are trying to make the pug do what the blungers ought to do, and I absolutely agree when I hear him say that we are giving all clays the same amount of soaking or blunging. I am convinced that there is more bad clay given to the potters to-day through inefficient blunging of the ball clay than through any other reason.

Mr. D. F. W. Bishop:—I quite agree with Mr. Shaw that, if we could get a pug that would set right all the faults that have occurred in every other department before the clay has reached the sliphouse, the pug man's job would be very much lighter, and incidentally so would the manufacturer's. There is one thing that struck me, however, as being doubtful policy. I rather gathered that Mr. Shaw meant that the knives at the entrance of the casing should not only be greater in number, but should be placed with more slope; and then, in the middle of the casing they should be straighter, whilst further along, towards the exit end of the pug, they should have more slope again in order to thrust the clay out. I would like to suggest for your consideration that this would surely mean that the pressure would not be even throughout the whole length of the casing, and that is a very important

point, it seems to me—the pressure should be uniform.

With regard to Mr. Hollins' paper, there was only one matter which, by subsequent discussion, did not seem to be cleared up, and that is his reference to 90 revolutions, to which Major Moore called attention. I myself could not understand that. It is probably some slight mistake on the part of Mr. Hollins. Maybe he has left out a decimal point, or was it that he meant to refer to 90 revolutions as the speed of the engine at the time ? Of course a pug mill cannot possibly go at anything like that speed. I was interested to see the two slides which Mr. Hollins put before us of the pug mill in use at Shelley's factory, but surely that is a mortar mill rather than a pugmill.

MR. HOLLINS:—No, not at all. There is not the slightest similarity between the pug mill shewn on the screen and a mortar mill. With regard to the 90 revolutions per minute, I have given the exact figure mentioned by Lane, but I do not want you to stress this point too much, as he evidently was dealing with dry clays, for in the same paper he refers to the "usual number of revolutions of pug shafts, in England, as being 18 to 25 per minute." I have endeavoured to avoid anything which would drag me into a discussion of technical points. It is rather more the practical side of the problem with which I want to deal, and to suggest that experiments should be made to find the proper speed of the pug mill shafts which will produce the best grade of clay. Some quite elaborate tables have been worked out by Bourry on the speed at which pugs should be driven with different kinds of clay. As I pointed out in the early part of my paper, in the past we have put down a pug mill and put someone in charge of it, and we have expected this to be the end of all things. But I believe that there should be as much care in seeing the clay through the pug mill as is devoted, or should be devoted, to the mixing of the clay in the blungers.

Major Moore's second point is beyond the scope of my address, but while one may agree that ball clays, in some cases are not sufficiently blunged, one could not accept the statement that it is a greater source of bad clay to the potters than "improperly pugged clay." We mix our slop flint and our ball clay in the wet, and by the mere fact that we mix these together and agitate them we are doing more for the mixing of clay body material than the pug mill can ever accomplish.

MR. SHAW:—To make my point a little clearer with regard to the pressure. Supposing, we will say, that we are pugging a press of clay and the pug is full and we go on pugging, without further charging the pug, until we can pug no more. The last lump will be in a practically solid condition, although the pug is empty. But if we start refilling the pug we shall want at least a dozen lengths cutting off and throwing back before we can get it solid again. This, I think, proves my point that it is not necessary

to have the knives set at a driving power for two-thirds of the length of the pug. All that we want to do is to allow for the shredding and for the mixing. We should still have pressure enough and driving power enough on the last length of the knives to press out the clay in solid lumps as we require it.

Mr. F. Wooldridge:—I have had a rather extensive experience of pugging, and am conversant with the machine which has been described in the lantern slides. I daresay Mr. Hollins will remember that nine or ten years ago we had a talk in regard to this type of machine. It may be useful to some of the members present to-night to know that that machine is purely and simply a kneading machine. The unfortunate part of that machine is that it only delivers about two hundredweights every 25 minutes. But there is a peculiar thing which takes place in its operation. I have tested it with clay of one consistency, and I have found that after about 25 minutes' working the clay gets worse instead of better, although the air bubbles have been excluded. By lengthy experiments we find that 25 minutes' working produced the best quality of clay. It struck me that Mr. Hollins' paper is an attempt to generalise on all kinds of pugging. But I think that if the matter were dissected up and the various kinds of bodies with which we have to deal were dealt with separately, we should make better progress towards getting improved products through the pugs.

I perfectly agree with Major Moore as to what he says about blunging. In my opinion this is tremendously important. And there is another thing; after blunging there should be efficient agitation, but I believe that blunging has more to do with the trouble than anything else.

With regard to the vertical pug. I had some experience in pugging the first lot of china body which was pugged in this district through a vertical pug, and we got a peculiar result. The exit, by the way, was parallel with the shaft. The pugged clay was cut into cross sections and made up into plates, and we got a screwed formation on the surface of the plates, after firing, the same as you would expect to get from the cutting of the knives which roll the clay. It reminded one of the formation of a jam rolly pudding The pugged clay could be unrolled into one flat piece. I experimented with this and found that by putting in a Maltese cross after the clay in the course of its extraction passed the bottom knife, thereby cutting it up into four separate sections instead of letting it be pushed down and forced out in one piece, we were able, by restricting the orifice, to extract the four separate sections together and thus form a homogeneous mass from which we could jolley china plates without the above defect. This is now universal, I believe, in pugs of this type which are used for china bodies. But this does not seem to get us very much further with regard to earthenware bodies, such as are used for the heavier types of ware. I simply mention it in order to show that increasing

your speed will not help you with all kinds of clays of different softnesses, which may be required for the various operations. The speeding up of the pug for a stiff body may give you a certain result, but it certainly will not give it you for a softer body. It seems to me that the only thing to do is to tackle this thing both from a china point of view and an earthenware point of view, and I should certainly cut the china again into two parts, the one that is made without ball clay and the one that is made with.

Mr. Harold J. Plant:—I think this meeting to-night is a tribute to Mr. Hollins. He has here a very fine audience composed of all types of persons interested in pottery production—operatives, managers and manufacturers. He has given us a most instructive paper and there has been a very interesting discussion. The subject is one that is undoubtedly of vital importance to all who have to make pots. I am glad that Mr. Wooldridge answered that question with regard to the roller pug mill—if we may call it a pug mill—because I suppose the reason why that mill has not been generally adopted in the china trade is that it is necessary to get output. I am, unfortunately, one of those poor manufacturers who have had to try to make a living at one time by producing china cups and saucers at 2/6 a dozen, and, invariably, the question of the installation of a roller mill was ruled out as it was considered to be impossible to get the necessary output without installing half a dozen or so of these mills, which would have been too expensive a matter in a cheap industry such as the Longton china trade at one time was.

I have been very much interested in what Major Moore has said, and also what Mr. Shaw has said, but I do not think when they talk about blunging they go far enough back. The getting of good clay starts earlier than that. A good deal of the clay that the potters use is spoiled by the millers before ever it gets on to the factories. You cannot possibly make good plastic clay out of a mixture of sand and sawdust. Then again, the materials may be burned in the drying. You have here another hopeless proposition for the potter who is seeking to produce a truly homogeneous body. It is necessary, therefore, that we should start right from the very beginning. Another point, we must see that the materials themselves are right, that our china clay and our ball clay are right to begin with. I know of some manufacturers who are foolish enough to pay 36/- a ton for china clay because they consider it to be cheap, but if they only knew it is the very dearest thing they could possibly buy. The china manufacturer, to be successful, requires the finest and most plastic china clay that it is possible for him to lay his hands upon—no matter what it costs within reason. Given such materials, good grinding, perfect evenness of grain and full plasticity, through adequate weathering, perfect mixing and proper blunging, the pug mill then stands a chance of turning out an article that the potter can use successfully.

As an instance of the effect of china clay, I may say that I consider the commencement of my success as a potter came about through one thing and one thing only. In short, I dared to change one brand of china clay for another which I believed to be better. As a result of that change we reduced our pitchers to one quarter, and we have kept the reduction ever since, and that was 20 years ago. I calculated that the change resulted during the first year in a saving of well over a thousand pounds, and we have never looked back since that time when we dared to change our china clay against all the advice and the experience which we had received in our previous years of trading.

I think the question of pugging has been discussed very fully to-night, and there is nothing for me to enlarge upon there. As to whether the pug goes at 90 revolutions a minute or 30 to 40, as I believe to be more correct in the case of the china trade, this is a matter which you have to settle for yourselves. I do think, however, that most manufacturers make a fatal mistake in not making special provision for the storage of the clay after it has come from the press. I have just taken over another business, and although it is a successful business, I do not think that at the utmost we have room to store more than four or five tons of clay, and the result is that we are always up against the difficulty of having to work with a "short" body. But some manufacturers who are better placed through having room to store *will* insist on putting their clay flags where a draught is blowing across them all the time, with the result that trouble is constantly experienced through the surface of the clay becoming hard, whilst internally the clay is more or less soft. The poor old pug, as Mr. Shaw says, has to try to put all these things right, and it is a practical impossibility,

Another point I would like to mention is this: the pug should be cleaned out and the knives examined at least once a week. We find in a pug mill all sorts of rubbish, bits of wire, presscloth, bits of wood, and all kinds of things. I believe that this has a lot to do with such difficulties as we have been discussing to-night. The Technical Committee of the china manufacturers has tried its best to settle some of these things and it has not succeeded in getting to the bottom of them—such matters, for instance, as the little blibs that occur on the surface of ware which make all the difference between a beautiful and perfect glazed surface and a disappointing surface which breaks the heart of a decorative manager and, incidentally, spoils heaps of ware that might otherwise be suitable for groundlaid colours. I am not speaking now of air bubbles due to faults in the glaze or pin holes in the firing, but fine and minute holes in the biscuit china body. It may be that the earthenware manufacturers get similar difficulties. I do not know much about that, as I have only a very superficial knowledge of earthenware. But I do know that in china great loss, incon-

venience and utter disappointment is often caused through this difficulty in getting the body perfectly solid throughout. Whether any type of pug mill will ever do it or not I cannot say. Whether wedging after the pugging will do it I do not know. But having been here to-night I have been caused to think of certain remedies that might possibly be tried. The Ceramic Society could certainly do some very good work if it would endeavour to solve this question. Certainly it would be of great advantage to the Longton china potters.

I have been very glad to hear Mr. Hollins to-night. He has one quality that is very valuable to a potter, and that is tenacity. He does stick to his points. I have sat with him on the same Board, he on one side of the table and I on the other, and I know that many times he has continued to hammer home a point in face of considerable opposition. The problem that he has been discussing to-night is one which does considerably affect the wage-earner, and it also considerably affects the profits of the manufacturer. I am very pleased, therefore, to move a vote of thanks to Mr. Hollins for his interesting paper. We are grateful to him for having come before us and we are glad that the paper has given rise to such an interesting discussion.

Mr. F. Turner:—After Mr. Plant's remarks I think that my task will be quite an easy one. Of course, Mr. Plant is a china expert. I am not. But I do know that the question is just as important to an earthenware as it is to a china manufacturer. The paper started off be referring to the question of the pugging of clay, but the subject appears to have taken a broader aspect and now we are dealing with the question of the production of good clay, and if we are going to talk about good clay, as Mr. Plant says, one must go a long way back. All the things which have been mentioned are important, and there are some others also which have not been mentioned. Take, for instance, an ordinary earthenware manufacturer. If he can weather his ball clay it will help him. But perhaps he cannot. Unfortunately, the worker has to handle clay on a factory where there is no room at all to store. Honestly, how some slipmakers can get six or seven different bodies through surprises me. I should certainly not like to have their job. To get these different bodies through two filter presses and one pug is indeed a problem. To my mind, there is no man on the factory who goes through the mill like the slipmaker. If he supplies just the right sort of clay to one hollow-ware presser, he probably will not suit the next one. We talk about the production of a stiff clay for a large-ware jiggerer, and if he gets it a bit softer than suits him he does not like it and he complains. Some jiggerers I know certainly would. But the question of hard and soft clay is of even greater importance to the manufacturer than it is to the workman. For if a workman has loss, the manufacturer will have considerably more loss, and,

therefore, such attention as the manufacturer pays to the improvement of his body will be repaid to him a thousand fold. It is obvious that no workman can produce good ware for a manufacturer from bad clay. But given the right conditions in the early stages of body mixing, you can still have some very badly pugged clay. I look upon the pug as a mixer and a consolidator. Although you have perfectly pressed clay, that perfectly pressed clay is both hard and soft. I do not care what filterpress you use, the clay is not homogeneous throughout its section, and of course, if you have badly pressed clay, some rolls soft and some hard, there is no pug on earth that will make good clay out of them. The best thing is to put that clay back again. Soft clay cannot properly be pugged. But even with properly pressed clay, you get hard and soft clay, and the function of the pug is to cut it up and mix as well as possible, afterwards consolidating it. The pug usually succeeds in doing it fairly well. But I agree with Mr. Shaw that we have not yet attained to the perfect design in pugmills. There is no doubt that there must be a definite relationship between the angle of the knives, the diameter and length of the body of the pug and the orifice. You have got to cut the clay and consolidate it. If you get the clay more solid on the outside than it is in the middle it is unsatisfactory. If the clay is too soft to begin with you cannot make it solid, and the idea of placing a water tap over a pug is wrong. I also entirely disagree with the feeding of scraps into the pug. The pug is not a blunger, and you cannot make it into one. First of all we must be sure that the clay is properly pressed. If various men want various degrees of hardness or softness, the best way is to select the clay first and not try to make it softer in the pug. If you feed water into a pug it makes the clay soft; of course it will; but I do not agree that it will yield good clay. My experience of clay made soft in a pug is that you are liable to get pin holes in the body—in fact, the difficulty will be to do without them. I have seen hundreds of pin holes in ware made from clay which has been too hard and an attempt has been made to make it softer in the pug. The only satisfactory way is, to select the clays before they come into the pug. But when the clay that is fed into the pug is as perfect as possible, it is still undoubtedly important that the pug shall be properly fed. It should be kept full. If you get a pug which is half run out and start to feed it again, you cannot expect that the first part of the clay and the second are going to be equally good. The usual practice of the slipmaker when starting a pug is to take ten or a dozen lengths, or as many lengths as his experience has assured him to be best, and throw these back again. Some manufacturers find it an advantage to pug their clay twice. I do not know that it makes the clay any more plastic, but think that it makes it much more even. The idea of the pug, to my mind, is not to make the clay plastic. That should have been done before the

clay gets to the pug mill. The function of the pug is to make the clay perfectly even so far as pressure and the distribution of water are concerned. The more water you have, the more contraction you will have, and the more solid the clay, the less it will contract. Hard and soft clay is not a question of water only, but also a question of pressure, and that is why some manufacturers prefer to pug their clay twice. I have the greatest pleasure in seconding Mr. Plant's resolution. Mr. Hollins certainly does stick to his points, and I feel that he came here to-night with a perfectly clear and sincere desire to put before the Society an idea which might promote some useful discussion. In this, he has been successful, and if the discussion results in the production of better clay, benefiting the workers and benefiting the pots produced, Mr. Hollins' effort will have been well worth the time and trouble expended.

Mr. H. E. Wood:—I would like to support what the mover and seconder of the vote of thanks have said. I think you will agree that Mr. Hollins, in bringing this matter to our notice, has served a very useful purpose. He has started a good deal of talking and I hope a good deal of thinking also. Many here to-night who have not spoken have no doubt been thinking very seriously on these matters. But do not let it be thought that we have not considered these things before. We have thought about them very much. I could tell you some very peculiar experiences in regard to pugs, but I do not want to do that to-night. You have heard the subject very well ventilated, but I do not think that this Society is the kind of Society which is going to move a resolution that a pug shall be constructed just so and so. I think the object of this Society is to stimulate thought, and to encourage each invidual to consider his own particular set of conditions. Mr. Wooldridge's point is a very good one indeed, and one of the main points to be considered in regard to a pug. You cannot expect a pug to deal with all sorts of bodies and give in each case equally satisfactory results. You may have perfectly good results with one particular body and perfectly bad results with another. It means that everyone of us must try to deal with his own particular troubles. But when we have a perfect pug and a perfect sliphouse, we shall still have the human element to consider, and that, of itself, is a very serious factor in this matter of pugging clay.

Mr. Hollins:—I thank you, gentlemen, for the vote of thanks so heartily accorded, but in passing this you are doing more for the National Pottery Workers' Society than for me, because some of the thoughts in this paper have been contributed by my colleagues, and I have been responsible for inserting them. I think Mr. Turner has crossed the T's and dotted the I's of my paper in every sense and form. With regard to the angle of the knives and the diameter of the pug and the orifice, these are the things which you will have to determine for yourselves. The

technical experts, with your guiding opinions, are the people who should be brought in. In my paper I was assuming that the horizontal pug, being the one in general use, is performing certain functions, but it is because you do not use this to the best advantage that I have been speaking to-night. At the present time there is very little organisation in the sliphouse, and it is because of this that I am here. As to the maturing of clays, I remember in my early experience that it was the practice on some of the factories to store clay in cellars for maturing. I have never seen this kind of arrangement since, and it appears to me that in this direction during recent years the pottery industry has not moved forward. I have read in some number of the Ceramic Society's "TRANSACTIONS" that it is necessary that this should be done. The clay should not only be matured on your clay slabs but matured after leaving the filterpresses and put into the pug. And it should again be matured some little time before going to the makers. If you were to do this you would probably get a kind of clay that would be more workable from the potter's point of view, and also reduce the loss of the manufacturer.

With regard to Mr. Wooldridge's remarks as to the machine in use at Messrs. Shelley's factory being a kneading machine, I entirely agree with him, and I think it would fit in with Mr. Harold Plant's point of view when he speaks of the difficulties that he gets in connection with fine china bodies. Bourry states that "after pugging has been done the clay should be put through this kneading machine for fine china work, so as to eliminate the air bubbles which are always left in the most perfect pug mill." Broadly speaking, I should combine the use of the vertical pug along with the kneading machine for china and accept the horizontal type of pug mill for the general earthenware trade. But accepting this, it will still be necessary to consider the right control of the pug mill, and the operatives feel that there ought to be placed in charge of the pug mill a man who not only understands its uses, but also the requirements of the potters who are to use the clay. Unfortunately, very often anyone is put in charge of the pug mill, the job being considered a somewhat inferior one; whereas it is as important, in our opinion, as any other part of the clay processes.

I thank you, gentlemen, for having given me an opportunity of putting forward the operatives' point of view and for the excellent discussion which has taken place as a result of my paper. I hope it will have good effect in practice.

XII.—Terra Sigillata not Samian Ware.

[Communication from the Clay and Pottery Laboratory, Stoke-on-Trent. No. 104].

By J. W. Mellor.

(For the fundamental idea of this note I am indebted to a conversation I had some years ago with the late M. L. Solon. I was reminded of this by some recent publications on the so-called *terra sigillata*).

OVER two thousand years ago the white clay from the islands of Lemnos and Samos was well-known in Europe. It was called *Diana's earth* and *terra sigillata*, and used as a medicine. The beneficient virtues of this edible clay were extolled by the Greek writers in 300 B.C. The Lemnian earth was mentioned by Theophrastus, Dioscorides, and Pliny. The clay mine in the Lemnian hills was in charge of the priests of Diana who alone had the right of access. A supply of clay was extracted once a year as a solemn religious ceremony. The temple priests mixed the clay with the blood of goats, moulded it into pastils and impressed the slabs with the sacred symbol of Diana. Hence the name *terra sigillata*. In the Middle Ages, the edible clay was obtained from other localities and the tabloids were stamped with various symbols and legends. The earth was used as a panacea against all kinds of diseases.

So far as I can see, the early pharmacopœia contained three remedies. The medical man would proceed on his rounds with a jug of milk in his hand, some terra sigillata in his pocket, and a dog following on behind. The clay and milk were the remedies for all internal disorders, and the dog was used for external disorders, being trained to lick sores and scabs.

Collections of the various stamps used for this purpose have been made in several continental museums, and copies of three hundred and seventy such will be found in D. C. G. Ludwig's *Terrae musei regii Dresdensis*, (Lipsiae, 1749). The accompanying illustration (Fig. 1) is reduced from the first plate in that work.

Through some confusion, the red Samian pottery of the Romans has been in Germany wrongly called *terra sigillata*, and the mistake has been promulgated elsewhere. The object of this note, therefore, is to protest against the misuse of the term *terra sigillata*, for Samian pottery. So far as I can see, there is no justification whatever for continuing the confusion of the terms. Each term has a clear and definite meaning.

terra
Danica
Helenia
TERRA SIGILLATA
TERRA SIGILLATA
ABVO
TERRA SIGILLA
TA MONTIS
ACUTI
TER SIGIL
STREGON
TERRA SIGIL
STREGONIEN
SIS
TERRA SIGIL
STRIGONIEN
TERRA SIGILLA
STRICONIEN
SIS
TERRA SIGILLA
TAALBA GOLD
BERGENSIS
TERRA SIGILLA
TA GOLIB
TER SIGIL
GOLDB SI
LESIA
TER. SIGIL
IN GOLD
BERG
TER SIGIL
GOLDBERK
LESI
TERRA SIGILLATA
TERRA SIGILLATA
TERRA SIGILLATA

XIII.—Note on the Use of Fluorspar in Leadless Glazes.

[Communication from the Clay and Pottery Laboratory, Stoke-on-Trent. No. 105].

By J. W. Mellor.

DURING the last twelve years, students have yearly tried to soften the standard leadless glaze by substituting a portion of the lime by fluorspar and cryolite. So far as one can tell from small scale experiments, the substitution can be advantageously made to the extent of, say, half-a-dozen per cent.; after that the glaze begins to get turbid and opaque. The exact amount naturally varies with the composition of the glaze. Years ago I intended that one of the students should communicate to our Society the results of some typical experiments, but I continued to defer the matter until I could see clearly the part played by the fluorine in the proposed additions. I am not yet satisfied, but since I have noted that the proposed substitution is getting into use, I am compelled to put forward this note prematurely. A caution is necessary.

It is fairly certain that much of the fluorine of the fluorspar or cryolite remains in the glaze, but I am not certain what proportion, because of the lack of faith in the analysis. We also know that fluorspar in some vitreous bodies has given trouble by blistering when at temperatures in the vicinity of Cone 10 and 11. I am not, therefore, prepared to recommend definitely the addition of these fluoriferous minerals without the caution that conditions may arise where blistering may occur. I have seen blistering occasionally with cryolite, but not with fluorspar; the probablity is that, for low temperature glazes, the substitution will give no trouble. Whoever uses the substitution, therefore, must keep the glazes under probation until he knows what conditions favour the expulsion of the gas—probably as silicon fluoride—after the glaze has skinned over, because it would produce blistering.

XIV.—The Discovery of China Clay in Europe.

[Communication from the Clay and Pottery Laboratory, Stoke-on-Trent. No. 106.]

By J. W. Mellor.

THE earliest examples of the white and translucent pottery, imported to Europe from the Far East, excited universal admiration. The mysterious nature of the substance had kept alive, in the mind of many a plodding alchemist and potter, the ambition to discover the secret of the composition of the oriental porcelain. For a long time they could do little more than produce admirable substitutes. The natural clays which were known to enter into the constitution of the original Chinese porcelain were unobtainable, and were replaced by a mixture obtained from the ingenious combination of their materials. Of this kind was the vitreous porcelain made at Florence by the Grand Duke Franscisco de Medici, and that made at Rouen by Louis Poterat, at the latter end of the 17th century. These imitations of the Chinese porcelain supply striking testimonials of the high degree of technical perfection attained.

It was not, however, that the existence of the beautiful white clay, to be known afterwards under the name of china clay or kaolin, and its possible application to the manufacture of pottery had remained unsuspected. Under the name of "Terra Sigillata" the fine and highly refractory earth was sold in losenges and tablets by the druggest as a remedy for all kinds of evils. Palissy tells us, in his memoires, that he had long experimented upon it. One of his successors, A. Clericy, styled himself "Ouvrier du Roy en Terre Sigillae." Neither of them, however, was able to turn his experiments to any particular advantage. The potters do not appear to have realised that an addition of felspar was required to impart fusibility to the clay, and that the mixture would have to be submitted to a much higher temperature than the one reached in the firing of common earthenware.

GERMANY.

The discovery due to J. F. Böttger, the German apothecary apprentice, who, in 1709, for the first time, manufactured hard porcelain in Europe, is an epoch in the annals of the ceramic art. In the course of empirical experiments, prosecuted, in the Dresden Laboratory, by order of Augustus the Strong, King of Poland and Elector of Saxony, young Böttger had occasion to examine some samples of white clay, of which extensive deposits existed at Aue near Schneeberg. Although the chief objects of these experiments were ostensibly in quest of the philosopher's stone and the transmutation of metals, strenuous efforts were also directed toward

the invention of a new kind of pottery. Böttger, who was then producing an admirable red body of so dense and hard a texture that it could receive on the lapidary's wheel a polish equal to that of a precious stone, appears to have no difficulty in recognising in the clay and stone submitted to his examination, the constitutive substances of the Oriental porcelain, namely, the kaolin and Pe-tun-sei, which the Chinese described as being, respectively, the bones and flesh of the paste. Towards 1710, the regular manufacture of a hard porcelain, quite similar to the Oriental ware in its physical constitution as well as its external appearance, was being briskly conducted at Meissen. In the official deed by which Augustus the Strong provided for the establishment and maintenance of his Royal Porcelain Manufactory, it is specified that the ware is to be made from Terra Sigillata.

Gradually, the source from which the indispensable raw materials could be obtained became known to a few practical potters, and several porcelain works were started in different parts of Germany; but the secret was so jealously guarded that it was comparatively a long time before it penetrated into other countries.

FRANCE.

In France, Count de Brancas Lauraguais was the first to discover real china clay, in the vicinity of Alençon. With it, he produced hard porcelain as early as 1758. Owing to the impurity of the clay the porcelain was, however, of such a poor quality that the manufacture never went beyond the experimental stage. In 1765, Mme. Darnet, the wife of a medical man of St. Yrieix, near Limoges, noticed a white clay abundant in the locality. She anticipated that it could be used in the laundries as a kind of natural soap. To be quite certain of this point, she sent some samples of it to a druggist named Villaris, in Bordeaux, who, after an examination of the samples, reported them to be true kaolin and felspar, the discovery of which was so anxiously hoped for by the French Potters. He at once communicated his observations to Macquer, chemist of the Royal Manufactory of Sèvres. Macquer, fully alive to the importance of the discovery, lost no time in repairing to St. Yrieix. There he satisfied himself that the porcelain clay and stone which occurred in the locality were of the finest quality, and promised to yield an apparently inexhaustible supply. From that day the extraction of the raw material and the preparation of the body made of the lonesome village an active centre of business prosperity.

ENGLAND.

The discovery of china clay in England is not due to the accidental recognition of a natural substance, so far left unnoticed; but it is rather the result of an untiring search by William Cook-

worthy, the keeper of a modest chemist shop at Cardiff. Cookworthy was a learned man, bent on applying to some practical purpose the results of his scientific studies. He had an irresistible attraction towards mastering the secret of the hard porcelain. Over and over again, he had read the letters of Pere d'Entrecolles, in which the process of manufacture used by the Chinese are so accurately described. Having often travelled through Cornwall, he noticed in that district a variety of clays and rocks which seemed to answer the description of the requisite materials given by the Jesuit missionary. From this, he foresaw the possibility of manufacturing hard porcelain with natural substances found in English soils. For ten years he experimented on samples obtained from various localities, but with only a partial result. At last, in 1768, he discovered at St. Stephen, near St. Austell, deposits of china clay and felspar which gave a completely satisfactory result. In the same year, Cookworthy applied for and obtained a patent which secured to him the exclusive right of using these materials in the manufacture of pottery. He established works in succession—at Plymouth and at Bristol—in which hard porcelain of typical character was regularly produced. On account of some practical considerations, not easy to determine, this kind of manufacture was altogether abandoned after a few years of unremunerative efforts.

The discovery of Cookworthy, however, soon proved an ever increasing source of wealth to British Industry. Not only were the china clay and stone of Cornwall employed with great advantage in improving china and earthenware bodies, but the china clay was also largely introduced in the modified technical processes of many other trades, such as cotton fabrics, paper-making, etc.; in many cases not always to the betterment of the quality of the fabric.

XV.—Note on the Use of Woodwool as a Packing Material.

By B. Olsen.

IN the last quarter of 1923, the restrictions affecting the use of straw for packing, now so generally enforced by overseas countries from fear of its acting as a carrier of the Foot and Mouth Disease, were already foreshadowed. Means were sought by which it might be effectively disinfected without deterioration, and as an alternative, it appeared highly desirable to find an effective substitute.

It occurred to Dr. Mellor that, on the occasion of the Ceramic Society's visit to Sweden, he had seen at the Gustafsberg Works a machine in operation producing woodwool for the packing of the china and earthenware manufactured there. By a fortunate coincidence, Mr. A. S. W. Odelberg was at the moment paying a brief visit to this district, and with his usual alacrity to be of service to his friends, the Pottery Manufacturers of this country, he accepted an invitation to a meeting of the Federation, so that he might give them the benefit of his experience. As I had the privilege of being present on that occasion, Dr. Mellor suggested that it might serve a useful purpose, if I embodied in a note to this Society the substance of my recollections of the discussion and of the subsequent correspondence which passed through my hands.

During the war, Sweden suffered from a scarcity of food stuffs, just as we did in this country. Straw became so important as fodder, that its use for other purposes was forbidden. Mr. Odelberg found himself confronted with the difficulty of having to find other means of packing his ware. On learning from a friend in the glass trade that he was successfully using woodwool, Mr. Odelberg at once realised that a packing material suitable for such fragile articles would prove ideal for china and earthenware. He decided to produce himself all that he required, and promptly installed a machine, using as raw material the pit props which, owing to the tyranny of the submarine, could not be exported to this country.

From the first the new packing material proved a great success, and also, since straw attained unheard-of prices, a very economical substitute. After the end of the war straw fell greatly in price, and is now much cheaper than its competitor. Mr. Odelberg has not, however, discontinued the use of woodwool, having what he considers good and sufficient reasons for his preference.

First and foremost comes the question of breakages. These have been so low since using woodwool, that he reckons he is saving the difference in cost on this item alone. He believes this is partly explained by the greater tendency of straw to swell or shrink owing to variations of moisture content, so that ware tightly packed when

leaving the factory may arrive at the other end of the journey in a loosely packed condition with consequent breakages.

A second consideration, to which he attaches much weight, is the exceedingly clean and hygienic nature of this method of packing. The health of the island community at Gustafsberg is good, and the death rate exceedingly low, but while straw was used with its usual accompaniment of dust, this was, unfortunately, not the case in the packing department, and lung trouble was only too frequent. Not unnaturally the men were inclined to prefer other work. Since the introduction of woodwool, the packing department is quite popular. In connection with the crisis through which we are passing, I would point out that the germ-free character of woodwool places it above suspicion as a possible carrier of foot and mouth disease.

A third reason given by Mr. Odelberg is that this mode of packing pleases his customers. Not only do they receive their ware without breakage, but they in turn make good use of the woodwool in making up smaller packages for their customers, whereas straw deteriorates rapidly with age and repeated use.

A point which Mr. Odelberg stresses is that you cannot fully realize the merits of woodwool as a packing material, if you know it only in the form in which it comes to you in bales. Straight from the machine it is soft, pliable and elastic, whereas during compression and storage it is apt to become somewhat brittle, harsh and dry.

Neither the plant, nor the manufacture are costly. The machine he is using is a "Beronius" No. 1, made by Messrs. The Beronius Verkstad A.-B. of Eskilstuna, Sweden, who a few months ago quoted £70 15s. 0d. f.o.b. Swedish port. To ensure rigidity, the frame is a heavy one-piece casting, forming a firm foundation and support for driving pulleys and fly-wheel at one end, and a work-table with a space down the centre at the other. In this central space is a slide, to which a reciprocating movement is imparted by the eccentric driving rod attached to the fly-wheel. This slide carries a line of saw spurs, the object of which is to split the wood, the two knives lying behind subsequently planing it off in double layers. Interchangeable saw spurs corresponding to three different widths of woodwool are supplied.

Pieces of wood not more than about 18″ long and 7″ wide are held in position, and fed downward to the spurs and planing knives by an ingenious clamping apparatus, having two rollers provided with teeth, which firmly grip the wood. The small waste piece remaining at the end of the operation can be instantly replaced, and a new piece fixed in position by the action of a lever.

From 2½ cwt. to 1 ton approximately of woodwool are produced in 10 hours, the quantity varying with the thickness of the shaving. A larger, more elaborate and expensive machine is constructed by the makers, but the output of the smaller machine

just described is sufficient for the packing house of a large manufactory. Waste wood from timber yards and other sources may be quickly converted into woodwool.

Mr. Odelberg states his cost of manufacture as follows:

Price of Pit Props ..	Kr. 13 or say	16/3 per cubic metre
Sawing	2	2/6
Transport	2	2/6
Making the woodwool	5·30	6/7
Power, oil, etc. ..	2·00	2/6
	24·30	30/4

One cubic metre of props yields about 400 kg. of woodwool. Cost per kilo of woodwool about 6·1 öre or say a little less than a penny. Consumption of props $1\frac{1}{2}$ cubic metre per man and per day.

So far all that I have said has been in favour of woodwool, but we are always learning that what is very good in one country is not necessarily so good in another. Mr. Odelberg packs in cases, the usual Continental method of packing. In this country cases and hogsheads are used, but most of the ware is packed in crates. This is too good a method of packing to be lightly abandoned, and so far it has not been found practicable to use woodwool for packing crates. Mr. Odelberg suggested trying woodwool made in thicker strands, and it would seem worth while to make the experiment. Other expedients have, I believe, been tried, but so far I fear without much success. In any case, large quantities of woodwool are now being used in the Potteries.

XVI.—Electrical Porcelain: the Effect of Varying the Composition upon some of its Properties.*

By Ernest Watkin.

INTRODUCTION.

FOR use in electrical apparatus, insulating materials should possess high dielectric strength and specific resistance; a low temperature co-efficient of expansion and of resistance, high mechanical strength, and should be impervious to moisture. From its infancy as an electrical insulator, difficulties have attended the use of porcelain, and the demand for a more efficient insulator called for by the rapid development of high tension transmission lines, has placed before the electrical porcelain industry a series of difficult problems, as it is well known that the insulator is the chief weakness in the transmission of electrical energy at high voltages. There is no doubt that a great deal of inferior porcelain has been placed on the market which has not only been responsible for serious breakdowns and heavy losses, but has also undermined the electrical engineer's faith in porcelain insulators.

W. D. Peaslee, in presenting his conclusions in his paper "The Insulator Situation,"[1] makes the following statement:—"The porcelain insulator, as commercially available to-day is not a success; it is deteriorating too rapidly both in and out of use, and the gathered evidence points to certain inherent features of manufacture and composition that are responsible in large part for this unreasonable deterioration." From this remark, it is evident that the author does not condemn porcelain altogether, but that he believes its failure to be due to faulty composition and manufacture. In his paper "Insulator Failures,"[2] he states that he does not believe non-porous porcelain can be made. Strictly speaking, this statement is probably true; but tests made by the writer, the results of which are given in Table 8, do not confirm, but undoubtedly negative, his idea, that it is not possible to produce commercially, a porcelain insulator with less than a tenth of one per cent. porosity, which degree of porosity he gives as rendering porcelain worthless as an insulator. A number of causes have been brought forward in order to account for the deterioration and failure of porcelain insulators, chief amongst them being porosity.

Porcelains vary very widely in their physical properties, such

*Presented as a Thesis for the Pottery Diploma (1922-23).

as tensile and compressive strength, heat conductivity, thermal expansion, dielectric strength and electrical resistance, so that no definite values of these properties, as applying to porcelain, can be given. This is not to be wondered at when one considers the various compositions and stages of development represented by the different types of porcelain. Each type must have its own properties determined specially, before any values can be given. With this object in view, and in endeavouring to find out the effect of varying the composition upon these properties, the following work was done.

Range of Investigation. The experiments were made with bodies containing :—

1. A low to high content of felspar.
2. A low to high content of clay, but keeping within certain limits to secure good working properties.
3. No flint to high content of flint.
4. Substitution of zirconium silicate for flint.
5. Substitution of steatite for felspar.
6. Substitution of ball clay for china clay.
7. Substitution of red clay for china clay.

The percentage composition of each body is given in Table I. For each of the bodies, a suitable firing temperature was found by trial, vitreosity being the main object. All the specimens were fired in saggars placed in down-draught ovens, heat recorders being placed in each saggar so that a record could be kept of the actual firing. These temperatures designated by Watkin's Heat Recorders and Seger Cones are also recorded in Table I.

TABLE I.
COMPOSITION AND FIRING TEMPERATURES OF THE BODIES TESTED.

Material	1	2	3	4	5	6	7	8	9	10
China Clay	30	30	30	30	30	30	15	—	30	30
Ball Clay	25	25	25	25	15	35	40	20	25	25
Flint	30	20	10	—	30	10	—	15	—	20
Felspar	15	25	35	45	25	25	45	30	35	10
Red Clay	—	—	—	—	—	—	—	35	—	—
Zirconium	—	—	—	—	—	—	—	—	10	—
Steatite	—	—	—	—	—	—	—	—	—	15
Seger Cone No.	10+	10	9	8	9+	9	8	7	9	7
Watkin Recorder	32+	32	31	30	31+	31	30	29	31	29
Approx. Temp. Degrees Centigrade	1310°	1300°	1280°	1250°	1290°	1280°	1250°	1230°	1280°	1230°

Preparation of the bodies. The bodies, except in Nos. 9 and 10, were prepared in the usual way, being blunged, lawned through 150's lawn, magneted, filter-pressed, and pugged. In cases 9 and 10 there was not sufficient material available to filter press,

and therefore, the slip was partially dried in plaster moulds, the resulting mass being thoroughly wedged before being used. The working properties of all the bodies were good, but No. 5 was a little short in plasticity, and No. 6 rather inclined to wreathing and excessive contraction. During firing, No. 10 blistered if a greater heat than Cone 7 was recorded. No. 1 would in all probability be improved by having a higher firing temperature. All the tests were made on unglazed specimens.

ELECTRICAL TESTS. (Properties).

If it were not for the property of certain materials, known as insulators, of resisting the passage of electric currents, the existence of electricity would possibly never have been discovered. We still, however, do not know of any substance that is an absolute insulator, although in the case of the best dielectrics, such as porcelain, the current through the material, even at high electrical pressures, can only be measured by the most sensitive instruments. In determining the electrical resistance of any material, we have to consider two distinct characteristics, namely: (1) Specific Resistance; (2) Dielectric Strength. The former determines what leakage current will flow through the material under normal conditions, and is expressed in terms of resistance between opposite faces of a centimetre cube. The electric or dielectric strength of the material determines the potential difference to which a given thickness of material may be subjected without breakdown occurring by puncture.

A further important electrical property of a dielectric, which, however, has not been fully investigated in the present work, is its permittivity and power factor. Whenever a dielectric is subjected to an electric stress, some of the energy supplied is stored in the insulating material, and the permittivity of a dielectric is a measure of the electrical energy which a unit cube of the material can store as electro-static energy. The value obtained, expressed as a ratio to that value obtained with air used as the dielectric, is known as the dielectric or specific inductive capacity of the material. The energy thus stored up in the dielectric is mostly given back to the circuit when the pressure is removed or changed in direction, but a certain portion is lost due to internal friction of the dielectric. The amount of energy thus dissipated in the dielectric, expressed as a percentage of the total energy supplied to the dielectric, is termed the power factor.

SPECIFIC RESISTANCE TEST.

For the determination of the electrical specific resistance, specimens in two sizes were made of size and shape as shown in Fig. 1. These were all made by the casting process, which gave a fairly uniform thickness. This style of specimen was chosen because of the following advantages:—

1. The large conducting area and thinness of material ensure a relatively large current at the lower temperatures, while at the higher temperatures, the smaller cup is suitable.
2. A satisfactory contact can be made between the specimen and the electrodes by the use of a conducting fluid (mercury was used in these experiments).
3. The temperature can be easily regulated, and, with the mass of mercury round and inside the specimen, can be kept more uniform.

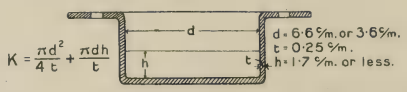


Fig. 1.

The apparatus was set up as shown in Fig. 2. A voltage of 200 D.C. supplied by a battery of Leclanche cells was applied to the terminals, and the insulation resistance was measured by the usual high sensibility series galvanometer, the time of electrification being two minutes. A guard ring was employed to prevent any surface

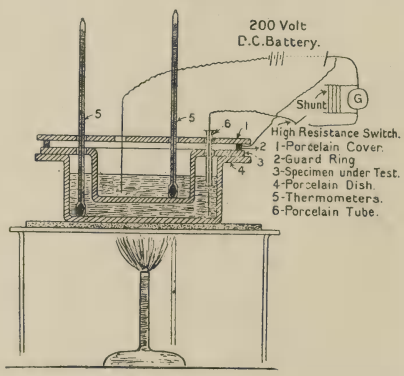


Fig. 2.

leakage affecting the results. An average of two or three tests was made before the final figures were recorded. The specific resistance in ohms per cubic centimetre was obtained by multiplying the observed resistance by a factor K, obtained by the formula :—

$$K = \frac{nd^2}{4t} + \frac{\pi dh}{t}$$

Where d = internal diameter of specimen in centimetres.
t = thickness of wall.
h = height of mercury inside.

The height of the mercury outside the cup was regulated to bring

it level, or slightly above, that inside the cup. The results obtained show a wide divergence, the resistivity varying from 5×10^{13} to 35×10^{13} ohms per cubic centimetre at a temperature of 20°C.

Classifying the results in order to see more clearly the effect of composition, we get :—

1. Increasing the amount of felspar at the expense of flint reduces the resistivity ; body No. 1, containing 15 per cent. felspar having approximately $2\frac{1}{2}$ times the resistance of body No. 4, containing 45 per cent. felspar (see Table II).
2. Increasing the amount of clay substance at the expense of flint slightly increases the resistivity (see Table III).
3. Substituting ball clay for china reduces the resistivity, Body No. 7 having approximately 60 per cent. the re sistance of Body No. 4 (see Table III).
4. Substituting red clay for china clay has little or no influence upon the resistivity. (see Table IV).
5. Substituting zirconium for flint has little or no influence upon the resistivity. (see Table IV).
6. Substituting steatite for felspar increases the resistance greatly ; body No. 10 having approximately 3 times the resistance of body No. 2 (see Table V).

After a careful study of the above results, it would appear that the resistivity is a function of the flux and that the use of felspar as a flux has an injurious effect upon the electrical resistance. That this effect is not due wholly to the reduced firing temperature is proved by the fact that the body with the greatest resistance has the lowest maturing temperature. In this case, the felspar has been partially replaced by steatite.

EFFECT OF HEAT UPON THE SPECIFIC RESISTANCE.

Increasing the temperature has for a long time been known to decrease materially the electrical resistance of porcelain. Haworth[3] gives the following figures :—

Temperature	Specific Resistance (Ohms per cubic c/m.)
17°C.	$50 \cdot 8 \times 10^{12}$
27°C.	$20 \cdot 0 \times 10^{12}$
37°C.	$8 \cdot 2 \times 10^{12}$
47°C.	$4 \cdot 0 \times 10^{12}$
57°C.	$1 \cdot 4 \times 10^{12}$
65°C.	$0 \cdot 64 \times 10^{12}$
82°C.	$0 \cdot 15 \times 10^{12}$

Bleininger[4] states that felspar is the important factor in lowering

the electrical resistance at high temperatures. Invariably, the higher the felspar content, the lower the resistance. By eliminating felspar and carrying the maturing temperature to a high point, bodies of high resistance at high temperatures were obtained. The same result is also reached when the felspar is replaced by silicates containing beryllium oxide, magnesia, or other alkaline earth. The relationship between the temperature and resistance is expressed in the formula :

$$\text{Log } R = a - bt.$$

Where R = Resistance of specimen in ohms.
t = Temperature in degrees C.
a and b are constants.

In the following experiments, the apparatus was used as shown in Fig. 2, the temperature being noted by high temperature thermometers. It was found that the temperature could be fairly well regulated by slow heating to a point above the required temperature ; turning the gas low, and allowing the whole to cool slowly, so that the temperature would tend to equalise throughout the specimen. Corrections were made to the observed temperature before being recorded. The results obtained show a very similar rate of decrease in the resistivity to that shown by Haworth. Without exception, all the bodies fall approximately 90% in resistance with a temperature rise of 30°C. ; 99% with a rise of 60°C. ; and 99·9% with an increase in temperature of 100°C. At the highest temperature at which readings were taken, viz. :—300°C., the specific electrical resistance of the various bodies ranged from 7 to

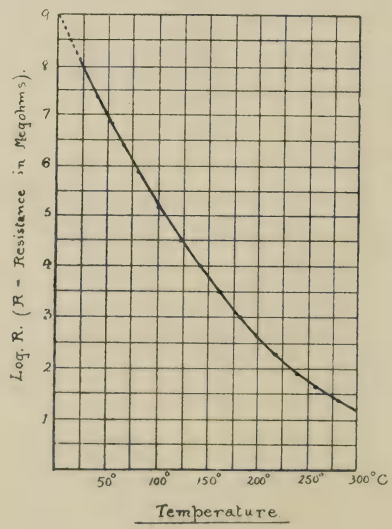


Fig. 3.

50 megohms. The complete results are given in Tables II. to V., and justify the conclusions already stated in regard to the effect of composition upon the specific resistance.

A typical curve showing the relation between temperature and resistance is shown in Fig. 3, the temperature being plotted against the logarithm of the resistance in megohms. This hardly conforms to the formula given by Bleininger, but his observations on the influence of felspar are confirmed. The statement made by Dantsize[5] that zirconia porcelain has a higher electrical resistance at high temperatures than ordinary porcelain, is not confirmed, as there is little to choose between bodies 3 and 9. This rapid decrease in resistance of electrical porcelain with increasing temperatures, introduces an important factor in the case of porcelains which may be subject to high temperatures when in use. The value of an

TABLE II.

EFFECT OF SUBSTITUTION OF FELSPAR FOR FLINT.

Body	1	2	3	4
Clay	55	55	55	55
Flint	30	20	10	—
Felspar	15	25	35	45
Firing Temp. ..	Cone 10 +	Cone 10	Cone 9	Cone 8
Watkin's Recorder	32 +	32	31	30

SPECIFIC ELECTRICAL RESISTIVITY. (OHMS PER C/M).

Temp.	1	2	3	4
20°C.	$16{\cdot}5 \times 10^{13}$	$12{\cdot}9 \times 10^{13}$	$10{\cdot}9 \times 10^{13}$	$6{\cdot}6 \times 10^{13}$
30°C.	$8{\cdot}0 \times 10^{13}$	$6{\cdot}2 \times 10^{13}$	$5{\cdot}2 \times 10^{13}$	$3{\cdot}1 \times 10^{13}$
40°C.	$3{\cdot}9 \times 10^{13}$	$3{\cdot}0 \times 10^{13}$	$2{\cdot}5 \times 10^{13}$	$1{\cdot}5 \times 10^{13}$
50°C.	$1{\cdot}9 \times 10^{13}$	$1{\cdot}5 \times 10^{13}$	$1{\cdot}3 \times 10^{13}$	$0{\cdot}8 \times 10^{13}$
60°C.	$9{\cdot}5 \times 10^{12}$	$6{\cdot}3 \times 10^{12}$	$4{\cdot}8 \times 10^{12}$	$3{\cdot}8 \times 10^{12}$
70°C.	$4{\cdot}8 \times 10^{12}$	$2{\cdot}7 \times 10^{12}$	$1{\cdot}9 \times 10^{12}$	$1{\cdot}7 \times 10^{12}$
80°C.	$2{\cdot}0 \times 10^{12}$	$1{\cdot}2 \times 10^{12}$	$0{\cdot}8 \times 10^{12}$	$0{\cdot}8 \times 10^{12}$
90°C.	$1{\cdot}0 \times 10^{12}$	$0{\cdot}5 \times 10^{12}$	$0{\cdot}3 \times 10^{12}$	$0{\cdot}3 \times 10^{12}$
100°C.	$4{\cdot}4 \times 10^{11}$	$2{\cdot}1 \times 10^{11}$	$1{\cdot}7 \times 10^{11}$	$1{\cdot}5 \times 10^{11}$
120°C.	$1{\cdot}1 \times 10^{11}$	$0{\cdot}5 \times 10^{11}$	$0{\cdot}4 \times 10^{11}$	$0{\cdot}4 \times 10^{11}$
140°C.	$2{\cdot}9 \times 10^{10}$	$1{\cdot}3 \times 10^{10}$	$1{\cdot}1 \times 10^{10}$	$1{\cdot}0 \times 10^{10}$
160°C.	$8{\cdot}3 \times 10^{9}$	$3{\cdot}9 \times 10^{9}$	$3{\cdot}2 \times 10^{9}$	$3{\cdot}1 \times 10^{9}$
180°C.	$2{\cdot}8 \times 10^{9}$	$1{\cdot}4 \times 10^{9}$	$1{\cdot}1 \times 10^{9}$	$1{\cdot}1 \times 10^{9}$
200°C.	$1{\cdot}0 \times 10^{9}$	$0{\cdot}6 \times 10^{9}$	$0{\cdot}4 \times 10^{3}$	$0{\cdot}4 \times 10^{9}$
220°C.	$4{\cdot}3 \times 10^{8}$	$2{\cdot}1 \times 10^{8}$	$1{\cdot}8 \times 10^{8}$	$1{\cdot}8 \times 10^{8}$
240°C.	$2{\cdot}0 \times 10^{8}$	$1{\cdot}0 \times 10^{8}$	$0{\cdot}8 \times 10^{8}$	$0{\cdot}8 \times 10^{8}$
260°C.	$8{\cdot}0 \times 10^{7}$	$5{\cdot}1 \times 10^{7}$	$3{\cdot}7 \times 10^{7}$	$3{\cdot}5 \times 10^{7}$
280°C.	$4{\cdot}6 \times 10^{7}$	$2{\cdot}9 \times 10^{7}$	$2{\cdot}1 \times 10^{7}$	$1{\cdot}8 \times 10^{7}$
300°C.	$2{\cdot}6 \times 10^{7}$	$1{\cdot}6 \times 10^{7}$	$1{\cdot}3 \times 10^{7}$	$1{\cdot}0 \times 10^{7}$

TABLE III.

EFFECT OF SUBSTITUTION OF BALL CLAY FOR FLINT; AND BALL CLAY FOR CHINA CLAY.

Body	5	6	4	7
China Clay ..	30	30	30	15
Ball Clay	15	35	25	40
Flint	30	10	—	—
Felspar	25	25	45	45
Firing Temp. ..	Cone 9	Cone 9	Cone 8	Cone 8
Watkin's Recorder	31	31	30	30

SPECIFIC ELECTRICAL RESISTIVITY. (OHMS PER C/M.)

Temp.	5	6	4	7
20°C.	$8{\cdot}5 \times 10^{13}$	$10{\cdot}9 \times 10^{13}$	$6{\cdot}6 \times 10^{13}$	$5{\cdot}3 \times 10^{13}$
30°C.	$4{\cdot}0 \times 10^{13}$	$5{\cdot}2 \times 10^{13}$	$3{\cdot}1 \times 10^{13}$	$2{\cdot}5 \times 10^{13}$
40°C.	$2{\cdot}0 \times 10^{13}$	$2{\cdot}5 \times 10^{13}$	$1{\cdot}5 \times 10^{13}$	$1{\cdot}3 \times 10^{13}$
50°C.	$1{\cdot}0 \times 10^{13}$	$1{\cdot}3 \times 10^{13}$	$0{\cdot}8 \times 10^{13}$	$0{\cdot}6 \times 10^{13}$
60°C.	$4{\cdot}2 \times 10^{12}$	$5{\cdot}4 \times 10^{12}$	$3{\cdot}8 \times 10^{12}$	$2{\cdot}1 \times 10^{12}$
70°C.	$1{\cdot}9 \times 10^{12}$	$2{\cdot}4 \times 10^{12}$	$1{\cdot}7 \times 10^{12}$	$0{\cdot}9 \times 10^{12}$
80°C.	$0{\cdot}8 \times 10^{12}$	$1{\cdot}0 \times 10^{12}$	$0{\cdot}8 \times 10^{12}$	$0{\cdot}4 \times 10^{12}$
90°C.	$0{\cdot}3 \times 10^{12}$	$0{\cdot}5 \times 10^{12}$	$0{\cdot}3 \times 10^{12}$	$0{\cdot}2 \times 10^{12}$
100°C.	$1{\cdot}4 \times 10^{11}$	$1{\cdot}8 \times 10^{11}$	$1{\cdot}5 \times 10^{11}$	$0{\cdot}7 \times 10^{11}$
120°C.	$0{\cdot}3 \times 10^{11}$	$0{\cdot}4 \times 10^{11}$	$0{\cdot}4 \times 10^{11}$	$0{\cdot}2 \times 10^{11}$
140°C.	$0{\cdot}8 \times 10^{10}$	$1{\cdot}1 \times 10^{10}$	$1{\cdot}0 \times 10^{10}$	$0{\cdot}5 \times 10^{10}$
160°C.	$3{\cdot}3 \times 10^{9}$	$3{\cdot}6 \times 10^{9}$	$3{\cdot}1 \times 10^{9}$	$1{\cdot}4 \times 10^{9}$
180°C.	$1{\cdot}0 \times 10^{9}$	$1{\cdot}2 \times 10^{9}$	$1{\cdot}1 \times 10^{9}$	$0{\cdot}5 \times 10^{9}$
200°C.	$0{\cdot}4 \times 10^{9}$	$0{\cdot}5 \times 10^{9}$	$0{\cdot}4 \times 10^{9}$	$0{\cdot}2 \times 10^{9}$
220°C.	$1{\cdot}8 \times 10^{8}$	$2{\cdot}1 \times 10^{8}$	$1{\cdot}8 \times 10^{8}$	$0{\cdot}9 \times 10^{8}$
240°C.	$0{\cdot}7 \times 10^{8}$	$0{\cdot}7 \times 10^{8}$	$0{\cdot}8 \times 10^{8}$	$0{\cdot}4 \times 10^{8}$
260°C.	$3{\cdot}5 \times 10^{7}$	$4{\cdot}1 \times 10^{7}$	$3{\cdot}5 \times 10^{7}$	$2{\cdot}1 \times 10^{7}$
280°C.	$2{\cdot}1 \times 10^{7}$	$2{\cdot}3 \times 10^{7}$	$1{\cdot}8 \times 10^{7}$	$1{\cdot}2 \times 10^{7}$
000°C.	$1{\cdot}2 \times 10^{7}$	$1{\cdot}5 \times 10^{7}$	$1{\cdot}0 \times 10^{7}$	$0{\cdot}7 \times 10^{7}$

TABLE IV.
EFFECT OF SUBSTITUTION OF RED CLAY FOR CHINA CLAY; AND ZIRCONIUM SILICATE FOR FLINT.

Body	2	8	3	9
China Clay ..	30	—	30	30
Ball Clay	25	20	25	25
Red Clay	—	35	—	—
Flint	20	15	10	—
Felspar	25	30	35	35
Zircon. Silicate ..	—	—	—	10
Firing Temp. ..	Cone 10	Cone 7	Cone 9	Cone 9
Watkin's Recorder	32	29	31	31

SPECIFIC ELECTRICAL RESISTIVITY. (OHMS PER C/M).

Temp.	2	8	3	9
20°C.	$12{\cdot}9 \times 10^{13}$	$10{\cdot}9 \times 10^{13}$	$10{\cdot}9 \times 10^{13}$	$10{\cdot}9 \times 10^{13}$
30°C.	$6{\cdot}2 \times 10^{13}$	$5{\cdot}2 \times 10^{13}$	$5{\cdot}2 \times 10^{13}$	$5{\cdot}2 \times 10^{13}$
40°C.	$3{\cdot}0 \times 10^{13}$	$2{\cdot}5 \times 10^{13}$	$2{\cdot}5 \times 10^{13}$	$2{\cdot}5 \times 10^{13}$
50°C.	$1{\cdot}5 \times 10^{13}$	$1{\cdot}3 \times 10^{13}$	$1{\cdot}3 \times 10^{13}$	$1{\cdot}1 \times 10^{13}$
60°C.	$6{\cdot}3 \times 10^{12}$	$6{\cdot}3 \times 10^{12}$	$4{\cdot}8 \times 10^{12}$	$4{\cdot}2 \times 10^{12}$
70°C.	$2{\cdot}7 \times 10^{12}$	$3{\cdot}2 \times 10^{12}$	$1{\cdot}9 \times 10^{12}$	$1{\cdot}8 \times 10^{12}$
80°C.	$1{\cdot}2 \times 10^{12}$	$1{\cdot}3 \times 10^{12}$	$0{\cdot}8 \times 10^{12}$	$0{\cdot}8 \times 10^{12}$
90°C.	$0{\cdot}5 \times 10^{12}$	$0{\cdot}6 \times 10^{12}$	$0{\cdot}3 \times 10^{12}$	$0{\cdot}3 \times 10^{12}$
100°C.	$2{\cdot}1 \times 10^{11}$	$2{\cdot}5 \times 10^{11}$	$1{\cdot}7 \times 10^{11}$	$1{\cdot}3 \times 10^{11}$
120°C.	$0{\cdot}5 \times 10^{11}$	$0{\cdot}6 \times 10^{11}$	$0{\cdot}4 \times 10^{11}$	$0{\cdot}3 \times 10^{11}$
140°C.	$1{\cdot}3 \times 10^{10}$	$1{\cdot}7 \times 10^{10}$	$1{\cdot}1 \times 10^{10}$	$0{\cdot}8 \times 10^{10}$
160°C.	$3{\cdot}9 \times 10^{9}$	$5{\cdot}6 \times 10^{9}$	$3{\cdot}2 \times 10^{9}$	$2{\cdot}4 \times 10^{9}$
180°C.	$1{\cdot}4 \times 10^{9}$	$2{\cdot}0 \times 10^{9}$	$1{\cdot}1 \times 10^{9}$	$0{\cdot}8 \times 10^{9}$
200°C.	$0{\cdot}6 \times 10^{9}$	$0{\cdot}8 \times 10^{9}$	$9{\cdot}4 \times 10^{9}$	$0{\cdot}3 \times 10^{9}$
220°C.	$2{\cdot}1 \times 10^{8}$	$3{\cdot}1 \times 10^{8}$	$1{\cdot}8 \times 10^{8}$	$1{\cdot}3 \times 10^{8}$
240°C.	$1{\cdot}0 \times 10^{8}$	$1{\cdot}4 \times 10^{8}$	$0{\cdot}8 \times 10^{8}$	$0{\cdot}6 \times 10^{8}$
260°C.	$5{\cdot}1 \times 10^{7}$	$7{\cdot}3 \times 10^{7}$	$3{\cdot}7 \times 10^{7}$	$3{\cdot}3 \times 10^{7}$
280°C.	$2{\cdot}9 \times 10^{7}$	$4{\cdot}1 \times 10^{7}$	$2{\cdot}1 \times 10^{7}$	$2{\cdot}0 \times 10^{7}$
300°C.	$1{\cdot}6 \times 10^{7}$	$3{\cdot}3 \times 10^{7}$	$1{\cdot}3 \times 10^{7}$	$1{\cdot}3 \times 10^{7}$

TABLE V.
EFFECT OF SUBSTITUTION OF STEATITE FOR FELSPAR.

Body	2	10
Clay	55	55
Flint	20	20
Felspar	25	10
Steatite	—	15
Firing Temp.	Cone 10	Cone 7
Watkin's Recorder ..	32	29

SPECIFIC ELECTRICAL RESISTIVITY. OHMS PER (C/M).

Temp.	2	10	Temp.	2	10
20°C.	$12{\cdot}9 \times 10^{13}$	$35{\cdot}5 \times 10^{13}$	140°C.	$1{\cdot}3 \times 10^{10}$	$4{\cdot}4 \times 10^{10}$
30°C.	$6{\cdot}2 \times 10^{13}$	$17{\cdot}3 \times 10^{13}$	160°C.	$3{\cdot}9 \times 10^{9}$	$13{\cdot}6 \times 10^{9}$
40°C.	$3{\cdot}0 \times 10^{13}$	$8{\cdot}6 \times 10^{13}$	180°C.	$1{\cdot}4 \times 10^{9}$	$4{\cdot}3 \times 10^{9}$
50°C.	$1{\cdot}5 \times 10^{13}$	$4{\cdot}2 \times 10^{13}$	200°C.	$0{\cdot}6 \times 10^{9}$	$1{\cdot}6 \times 10^{9}$
60°C.	$6{\cdot}3 \times 10^{12}$	$21{\cdot}0 \times 10^{12}$	220°C.	$2{\cdot}1 \times 10^{8}$	$6{\cdot}6 \times 10$
70°C.	$2{\cdot}7 \times 10^{12}$	$10{\cdot}0 \times 10^{12}$	240°C.	$1{\cdot}0 \times 10^{8}$	$2{\cdot}9 \times 10^{8}$
80°C.	$1{\cdot}2 \times 10^{12}$	$3{\cdot}8 \times 10^{12}$	260°C.	$0{\cdot}5 \times 10^{8}$	$1{\cdot}4 \times 10^{8}$
90°C.	$0{\cdot}5 \times 10^{12}$	$1{\cdot}9 \times 10^{12}$	280°C.	$2{\cdot}9 \times 10^{7}$	$7{\cdot}8 \times 10^{7}$
100°C.	$2{\cdot}1 \times 10^{11}$	$8{\cdot}4 \times 10^{11}$	300°C.	$1{\cdot}6 \times 10^{7}$	$5{\cdot}0 \times 10^{7}$
120°C.	$0{\cdot}5 \times 10^{11}$	$1{\cdot}8 \times 10^{11}$			

insulator depends upon its resistance, and if, as a result of heating by outside agencies, *e.g.*, sun's rays or sparking, the conductivity of an insulator is increased sufficiently, it will become still further heated by the current passing through it, until puncture takes place, or it ceases to be an insulator at all.

DIELECTRIC STRENGTH.

A number of investigations have been carried out by other experimenters bearing upon the effect of the composition of porcelain upon its dielectric strength, a brief reference to which is here given. Trieschel[6] states that porcelains high in felspar and low in quartz content are stronger dielectrically than those of low felspar and high quartz content, the amount of clay substance remaining the same. He further says that the replacement of quartz in electrical porcelains with various substances has always resulted in an increased dielectric strength. The theory put for-

ward to explain this is that the piezo-electrical property of quartz disturbs the structure of the porcelain, allowing a leakage of current through the voids caused by the deformation of the quartz crystals.

Bleininger[7], in his study of the dielectric behaviour of porcelains, comes to the conclusion that the dielectric strength depends more upon the sound vitrification of the porcelain than upon its composition and in this view he is supported by Montgomery[8]. Gilchrist and Klinefelter[9] found that the dielectric strength varied directly with the felspar content when this was high, but with low felspar it varied directly with the clay content. The dielectric strength varied inversely with increases of flint or china clay. The results given show a range of from 50 to 150 kilovolts per centimetre.

The dielectric strength or resistance to puncture of the porcelains was tested under the direction of Mr. J. L. Langton, M.Sc., M.I.E.E. at Manchester University. The experiments were carried out on cup shaped specimens as shown in Fig. 4. To

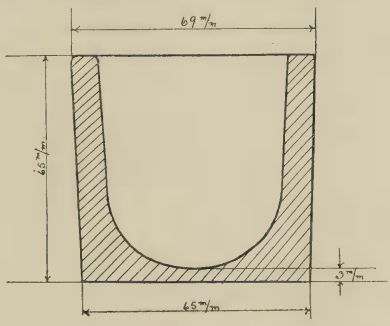


Fig. 4.

determine the electric strength of the specimens, an alternating electric stress was applied between the interior of the cup and the base which was earthed, and the puncture voltage was measured. After test, the cup was broken to allow inspection of the puncture, and measurements of the thinnest portion of the base were taken by means of a micrometer. The wave form of the generator supplying power to the testing transformer was practically sinusoidal. The peak ratio of the pressure wave form was determined to be:—

$$\frac{\text{Peak Value}}{\text{R.M.S. Value}} = 1{\cdot}46$$

so that the puncture pressure (peak value) in kilovolts is $V = 1{\cdot}46 \times$ puncture pressure (R.M.S.) in kilovolts.

The results, however, are not yet complete, but the following values of Momentary Dielectric Strength already determined will serve to indicate the relative values of the various porcelains in

this respect. Two batches of porcelains were tested by independent experimenters, and the average value in terms of peak volts per centimetre thickness is given in each case. In air, arc over occurred at about 30 KV, so that it was necessary to carry out the tests under oil. The voltage was applied as follows:—50 per cent. of the estimated puncture voltage was applied initially and then increased at the rate of 250 volts per second until puncture occurred.

The results are shown in Table VI.

TABLE VI.
MOMENTARY DIELECTRIC STRENGTH.
PEAK VOLTS PER C.M. THICKNESS.

Body	Batch 1	Batch 2	Average
*1	128,000	95,000	111,500
2	129,000	137,000	133,000
3	224,000	229,000	226,500
4	301,500	344,500	323,000
5	162,000	124,000	143,000
6	286,500	268,500	277,500
7	220,000	240,000	230,000
8	140,500	186,500	163,000
9	188,000	180,000	184,000
10	153,000	159,000	156,000

*Body No. 1 is suspected as not being sufficiently vitrified and further trials are being made on specimens which have received a higher firing temperature.

Conclusions.

1. Increasing the amount of felspar in the body at the expense of flint increases the dielectric strength. Compare Nos. 1, 2, 3, and 4.
2. Increasing the amount of clay substance at the expense of flint, increases the dielectric strength. Compare Nos. 5 and 6.
3. Substituting zirconium silicate for flint reduces slightly the dielectric strength. Compare Nos. 3 and 9.
4. Substituting ball clay for china clay reduces the dielectric strength. Compare Nos. 4 and 7.
5. Substituting red clay for china clay reduces the dielectric strength. Compare Nos. 3 and 8.
6. Substituting steatite for felspar increases slightly the dielectric strength. Compare Nos. 2 and 10.

EFFECT OF HEAT UPON THE DIELECTRIC STRENGTH.

The effect of heat upon the Dielectric Strength of Porcelain has been determined by Weimar and Dunn[15], who tested four different porcelains through a range of 300°C. They found that porcelain changes from a dielectric to a conductor progressively with increasing temperature, and at about 325°C., the electricity appears to spread and be conducted through the porcelain while it still offers a high resistance. The transition is gradual and is

affected by the composition of the porcelain. Bodies high in felspar are weaker at the higher temperatures than bodies low in felspar. Clay added at the expense of flint makes a stronger dielectric at the higher temperatures. Up to the present, only one of the experimental bodies has been tested for electric strength at increasing temperatures, but tests are being carried out, under the control of the British Electrical Research Association, on all the bodies, and

TABLE. VII. (Body 3)

Temp.	Thickness in c.m.	Puncture Voltage (R.M.S.)	Electric Strength Peak K.V. cm.
14°C.	0·284	46·0	254·0
61°	0·288	42·0	229·0
98°	0·340	49·0	229·0
104°	0·325	36·7	180·0
123°	0·327	19·6	95·6
150°	0·430	13·2	50·3
177°	0·446	8·8	30·8
192°	0·430	6·7	25·5
213°	0·460	4·5	16·2
220°	0·452	5·2	18·8
248°	0·430	2·7	10·2
*310°	0·390	2·5	10·4
*325°	0·305	1·0	5·2

*After prolonged application of pressure.

the results will be shortly available. The experiments were made on the cup shaped specimens as shown in Fig. 4 at increasing temperatures, placed in an electrically heated chamber.

The temperature was recorded by an electric pyrometer of the thermo-couple type. The results obtained (Body No. 3 only), given in Table VII. show that there is only a small decrease of dielectric strength between temperatures 15°C. and 100°C., and a very rapid decrease after 100°C. The shape of the electric strength temperature curve, as shown in Fig. 5, is very similar to that given by Weimar and Dunn, and can be accepted as a true characteristic for electrical porcelain.

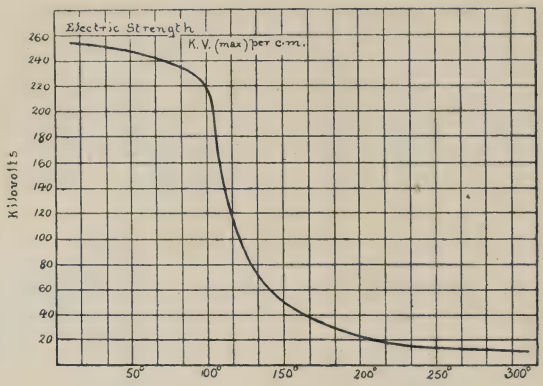


Fig. 5. Body No. 3.

POROSITY AND DENSITY DETERMINATION.

The specimens used in these experiments were the same as used in the mechanical strength tests. After being kept in a warm temperature for some time, they were carefully weighed, first in air, and then in air-free water. After being left immersed in water for 24 hours, during which time the water was boiled two or three times, they were taken out and the surface water removed before being reweighed. The results were checked by drying the pieces in a gas oven and weighing again. The Specific Gravity of the specimens was calculated from the formula :—

$$\frac{D}{D-A}, \text{ where } D = \text{weight of dry specimen.}$$

$$A = \text{weight suspended in water.}$$

Owing to the very small absorption of the test pieces this method gives fairly accurate results. Specimens (portions of the cups used in the dielectric tests) were also tested for porosity at Manchester University under the supervision of Mr. J. L. Langton, M.Sc.,M.I.E.E., by submitting them to a pressure of 2,000 lbs. per squareinch in an autoclave. Upon comparing these results (Table VIII) with the composition of the bodies, we find that :—

1. Substituting felspar for flint increases the specific gravity.
2. Substituting clay for flint increases the specific gravity.
3. Substituting zirconium for flint increases the specific gravity.
4. Substituting steatite for felspar decreases the specific gravity.

The porosity results show that by subjecting the specimens to high pressure, such as 2,000 lbs. per square inch, we get a much greater absorption than when immersed at ordinary atmospheric pressure. The values obtained, however, are so low, that we can consider the whole of the bodies to be vitreous.

TABLE VIII.

Body No.	Per cent absorption by weight		Apparent Specific Gravity
	24 hours Immersion	2,000 lbs. pressure	
1	0·027	0·0217	2·255
2	0·014	0·0269	2·305
3	0·013	0·0426	2·336
4	0·010	0·0315	2·343
5	0·014	0·0365	2·256
6	0·021	0·0363	2·298
7	0·010	0·0312	2·328
8	0·022	0·0583	2·359
9	0·034	0·0396	2·519
10	0·014	—	2·266

That the porosity of porcelain is a vital factor in its effect upon the electrical insulating properties is shown by the following experiments. Test pieces as shown in Fig. 6 were prepared and fired to different temperatures in order to get specimens of differing porosities. The pieces were carefully weighed and put into the testing bath as shown in Fig. 6a. The electrical resistance was measured hourly for the first eight hours, and afterwards each day for 14 days, when they were taken out and boiled in water for a short time. After wiping off the surface water the specimens were weighed and their porosities determined. The electrical resistance was also immediately retested, but no appreciable difference was observed from the last readings.

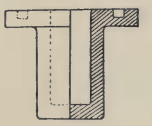


Fig 6.

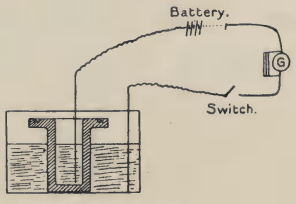


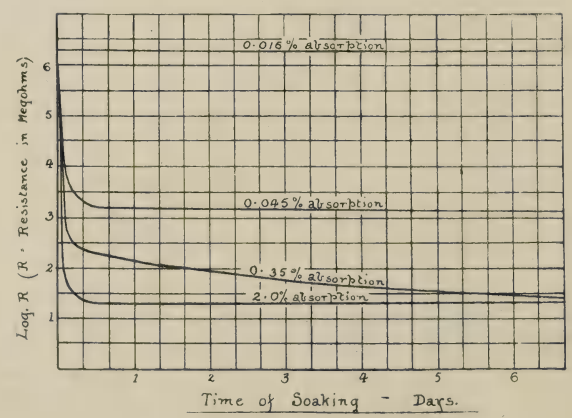
Fig. 6a.

An examination of the results which are given in Table IX, show that porcelain, having a porosity of 0·016 per cent. by weight, does not decrease in resistance at all during the 14 days immersion. Porcelain having a porosity of approximately 0·05 per cent. while giving a high initial resistance, is very rapidly reduced during the first 24 hours, after which it is reduced much more gradually, but quite steadily up to the end of the 14 days immersion. With an absorption of 0·35 per cent. the porcelain tested had only a very low resistance after one hour's immersion, showing approximately only one-thousandth of the resistance of a vitreous specimen. The resistance is also gradually reduced up to the end of the period of immersion. Specimens having a porosity of 2 per cent. give a

TABLE IX.
POROSITY AND RESISTANCE.

Time of Soaking	Per cent. Absorption by Weight.				
	0·007%	0·016%	0·048%	0·35%	2·0%
	Resistance in Megohms				
1 Hour	2,000,000	2,000,000	27,000	2,000	90
2 ,,	,,	,,	6,750	900	50
3 ,,	,,	,,	3,200	450	38
6 ,,	,,	,,	2,430	300	30
8 ,,	,,	,,	2,075	240	27
1 Day	,,	,,	1,700	160	23
2 ,,	,,	,,	1,600	90	,,
3 ,,	,,	,,	1,500	60	,,
5 ,,	,,	,,	1,370	35	,,
7 ,,	,,	,,	1,300	27	,,
14 ,,	,,	,,	965	23	,,

much smaller resistance, and at the end of 2 hours reached their minimum resistance, as no alteration took place during the remaining time of immersion. The electrical conductivity thus measured of the porous porcelain is mainly due to the moisture contained in the capillaries of the structure. Diagram No. 7 shows resulting curves, plotting resistance against time of soaking.



Fig, 7.

Shrader[10] has recently given some information on the relation of porosity and electrical resistivity of insulators, but, unfortunately, he does not give any values of porosity. He, however, states that resistance measurements are not sensitive enough to distinguish between porcelains having low porosities, and recommends the adoption of power-factor determinations. The effect of porosity

on the dielectric strength of porcelain has been shown by Professor Gustav Benischke[11] in rather an interesting manner. A number of insulators were placed in saggars one above the other in the same bungs, and as the firing temperature is higher in the top part of the oven, he obtained insulators having different degrees of vitrification. A duplicate set was placed in another bung, one set glazed, the other unglazed. The puncturing strength of each insulator was determined, and the results tabulated in order of their position in the oven.

	Unglazed	*Glazed*
Highest saggar	164,000 volts	160,000 volts
	166,000 ,,	163,000 ,,
	150,000 ,,	154,000 ,,
	153,000 ,,	149,000 ,,
	146,000 ,,	150,000 ,,
	145,000 ,,	146,000 ,,
	141,000 ,,	148,000 ,,
	143,000 ,,	137,000 ,,
	138,000 ,,	140,000 ,,
Lowest saggar	143,000 ,,	139,000 ,,

Taking an average, we get :—

Average of top three	..	159,500 volts
,, middle four	..	147,250 ,,
,, bottom three		140,000 ,,

These results show that the varying degree of vitrification due to the varying degrees of temperatures in the same oven, has a pronounced effect upon the dielectric strength of the porcelain. The puncturing of porcelain under high potential stress is one involving ionization, wherein the material becomes conducting at an accelerated rate, and the insulation fails suddenly. With porcelain that is not vitreous, it is probable that the minute voids containing air become ionized and the porcelain breaks down progressively when the electron bombardment becomes severe enough.

MECHANICAL STRENGTH.

The mechanical strength of porcelain has been tested by many investigators, but the results, when compared, are not at all uniform. This may be accounted for by the varying composition and degrees of vitrification of the porcelains, or by the method of testing and shape of test piece. Gilchrist and Klinefelter[9] found that the mechanical strength varied directly with the flint content, while an increase of china clay decreased it. Bleininger[4] states that the mechanical strength of porcelain, is increased by substituting zirconium oxide for flint. Peaslee[12], gives the maximum strength of ordinary porcelain as being 40,000 lbs. per sq. inch in compression, and 1,500 lbs. per sq. inch for tension.

Clarkson found that the tensile strength varied from 870 to 2,142 lbs. per sq. inch. Rieké and Gary[13], in their tests on eight different porcelains, report that the tensile strength varied from 2,250 to 4,500 lbs. per sq. inch. Demuth[14] gives a value of 3,420 lbs. per sq. inch for the tensile strength of porcelain, but states that the compression strength varies according to the size of the test piece. The smaller the test piece, the greater the specific strength recorded, varying from 14,000 lbs. for large pieces, up to 54,000 lbs. per sq. inch for small pieces. In the test on the bodies under consideration, the mechanical strength was determined by tensile tests made on unglazed specimens of size and shape as shown in Fig. 8, the cross sectional area at the critical point being approximately half a square inch.

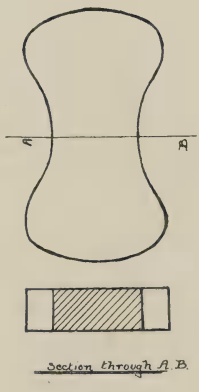


Fig. 8.

The tests were made in a Faiga machine. The specimen is placed in two jaws, one fixed, and the other attached to a movable arm which is gradually pulled away, the resistance in lbs. being recorded on a scale. The results are given in Table X. The *Results*—

TABLE X.

Body No.	Composition			A. Highest Tensile Strength	B. Average
1	Clay 55	Spar. 15	Flint 30	2,150 lbs. per sq. inch	1,790
2	,, 55	,, 25	,, 20	2,057 ,, ,, ,, ,,	1,800
3	,, 55	,, 35	,, 10	1,980 ,, ,, ,, ,,	1,800
4	,, 55	,, 45	,, —	1,740 ,, ,, ,, ,,	1,560
5	,, 45	,, 25	,, 30	2,054 ,, ,, ,, ,,	1,750
6	,, 65	,, 25	,, 10	1,406 ,, ,, ,, ,,	1,190
7	,, *55	,, 45	,, —	1,615 ,, ,, ,, ,,	1,310
8	,, –55	,, 30	,, 15	1,856 ,, ,, ,, ,,	1,800
9	,, 55	,, 35	Zircon 10	3,063 ,, ,, ,, ,,	2,720
10	,, 55	Steatite 15 } Spar 10 }	Flint 20	2,140 ,, ,, ,, ,,	2,010

*Contains excess ball clay. –Contains red clay.

highest values obtained are given in Column A, and it is these values which have been considered when drawing up the conclusions. The average values are given in Column B, but these may include results obtained on specimens containing flaws.

Comparing the results with the composition of the bodies, we find that :—

1. Increasing the proportion of felspar at the expense of flint, decreases the mechanical strength.
2. Increasing the proportion of clay substance at the expense of flint, also decreases the mechanical strength. Both these observations confirm the results obtained by Gilchrist and Klinefelter.
3. Substituting ball clay or red clay for china clay reduces the mechanical strength.
4. Substituting zirconium silicate for flint greatly increases the mechanical strength. This was also stated to be the case by Bleininger.
5. Substituting steatite for felspar does not affect materially the mechanical strength.

The results obtained are below the values given by German experimenters, but are quite comparable with the values given by the other investigators.

Summing up the conclusions already arrived at on the various properties, we find the effect of varying the composition of porcelain to be as follows :—

1. Substituting felspar for flint reduces the maturing temperature of the body, producing a more glassy structure, which has a higher specific gravity, but which is weaker mechanically. The specific electrical resistance is decreased, but the dielectric strength is increased. This evidence disproves any relationship between the specific resistance and dielectric strength.
2. Substituting clay substance for flint increases both the dielectric strength and specific resistance, but reduces the mechanical strength.
3. Substituting ball clay for china clay has a deleterious action on all properties investigated, electrical and mechanical.
4. Substituting red clay for china clay reduces slightly both the dielectric strength and specific resistance, also the mechanical strength. The mean values of bodies No. 2 and 3 should be taken when comparing with the red body No. 8.
5. Substituting zirconium silicate for flint greatly increases the mechanical strength, but has little influence on the electrical properties.

COMPARATIVE TABLE.

Body	Remarks	Specific Elec. Resist. Ohms per c.c.m. 20°C.	Specific Elec. Resist. 300°C.	Dielectric Strength Peak Volts per c.m. thickness	Tensile Strength lbs. per sq. inch
1	Substitution of Felspar for Flint.	$16{\cdot}5 \times 10^{13}$	$2{\cdot}6 \times 10^{7}$	112,000	2150
2		$12{\cdot}9 \times 10^{13}$	$1{\cdot}6 \times 10^{7}$	133,000	2057
3		$10{\cdot}9 \times 10^{13}$	$1{\cdot}3 \times 10^{7}$	226,000	1980
4		$6{\cdot}6 \times 10^{13}$	$1{\cdot}0 \times 10^{7}$	323,000	1740
5	Clay for Flint.	$8{\cdot}5 \times 10^{13}$	$1{\cdot}2 \times 10^{7}$	143,000	2054
6		$10{\cdot}9 \times 10^{13}$	$1{\cdot}5 \times 10^{7}$	277,000	1406
4	Ball Clay for China Clay.	$6{\cdot}6 \times 10^{13}$	$1{\cdot}0 \times 10^{7}$	323,000	1740
7		$5{\cdot}3 \times 10^{13}$	$0{\cdot}7 \times 10^{7}$	230,000	1615
2-3	Red Clay for China Clay.	$11{\cdot}9 \times 10^{13}$	$1{\cdot}5 \times 10^{7}$	180,000	2018
8		$10{\cdot}9 \times 10^{13}$	$3\ 3 \times 10^{7}$	163,000	1856
3	Zircon. for Flint.	$10{\cdot}9 \times 10^{13}$	$1{\cdot}3 \times 10^{7}$	226,000	1980
9		$10{\cdot}9 \times 10^{13}$	$1{\cdot}3 \times 10^{7}$	184,000	3063
2	Steatite for Felspar	$12{\cdot}9 \times 10^{13}$	$1{\cdot}6 \times 10^{7}$	133,000	2057
10		$35{\cdot}5 \times 10^{13}$	$5{\cdot}0 \times 10^{7}$	156,000	2140

6. Substituting steatite for felspar increases greatly the specific resistance, but has little effect upon the dielectric strength or the mechanical strength.

My grateful thanks are due, and I wish to express them here, to Mr. J. L. Langton, M.Sc.,M.I.E.E., of the University of Manchester, for the valuable and generous assistance I have received from him in the carrying out of the dielectric tests and absorption tests under pressure, put forward in this thesis, and also to the British Electrical and Allied Industries Research Association for permission to publish Fig. 5.

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DISCUSSION.

Mr. J. L. Langton (Communicated) :—Of all the insulating materials, electrical porcelain is the most suitable for outdoor use. Made from ingredients of mineral origin, it is more permanent in its chemical constitution than any other insulating material which has been tried for overhead line insulation.

The best British porcelain is unaffected chemically by the influence of ultra-violet rays of sunlight, atmospheric conditions, and by electric discharges. Deterioration is purely mechanical. It must be sought in the processes of manufacture—in the selection of the ingredients, in their proportion, in the thorough mixing, in the operations such as jollying, throwing, turning, etc., in the drying and—the most important of all—in the firing. The electric strength of the insulator is the most important property it requires. Given a suitable body, the electric strength of the insulator depends on its thorough vitrification, viz:—its correct firing, as well as avoidance of strains in the operations previously referred to.

An inspection of table VI. shows that bodies 3, 4, 6 and 7 have high dielectric strength; more or less correct firing is ensured by the

high proportion of flux. These bodies, however, do not show the highest mechanical strength. The tougher bodies (1, 2, 5 and 10) contain higher percentages of flint. Any introduction of impurer clays, as red clay, lowers the dielectric strength. In order to have a compromise of electric and mechanical strengths of the insulator, we require an ingredient to act as flint does. Further, to get the purest body, ball clay might be eliminated.

The troubles with porous insulators lie at the door of incorrect firing. Benischke's results on insulators taken from various saggars in the oven show where improvements can be made.

With vitrified porcelain, the percentage absorption even under 2,000 lbs. pressure cannot consistently be measured. It is far better to use the dye test (under pressure) to disclose a degree of porosity, if any.

A considerable amount of research work has been carried out at Manchester for the British Electrical and Allied Industries Research Association on the momentary dielectric strength (and at present on the duration strength) of electrical porcelain at various temperatures. These results, together with those on resistivity, absorption and a study of deposits on insulators, will probably be issued by the Association when the work is complete.

Figure 5 shows that porcelain up to 100 degs. C. is practically an insulator: the resistivity bears no relation to the dielectric strength. In fact a very porous body might have a higher resistivity than a vitrified body. Above 100 degs. C. the resistivity falls as shown in Figure 3, and then conduction has an influence on the dielectric strength as shown in Figure 5. The amount of current which can be forced through the material at, say, 400 degs. C. before puncture, is surprisingly large. The resistivity results obtained by the author are similar to those we have obtained with flat plates, using various direct voltages up to 800 volts. We found that the guard ring is not required beyond 100 degs. C.; that is to say, surface resistivity of clean porcelain below 100 degs. C., is due to moisture deposited.

An examination of the results shows that the ingredient influencing the resistivity is the flux-felspar. The ratio of the resistivities of bodies 1 to 4 is almost the ratio of the percentages of felspar. The lowering of No. 7 in contrast to No. 4 is due to fluxing material in the ball clay. A foreign body, as red clay, would keep up the resistivity at high temperatures. The results with steatite are particularly interesting. These results are important with insulators required for high temperature work, as sparking plugs and insulators for furnaces.

I wish to congratulate the author on his thesis. It is the first serious attempt in this country at correlating some of the important properties of porcelain with the percentage composition of its ingredients.

Dr. A. W. Ashton:—Mr. Watkin's paper has been, to me, a most interesting one, and I should like to congratulate him very heartily upon having presented to us a most valuable thesis. It points, I think, to some very interesting results, and the paper is one which I am inclined to regard as unique, since all the information appears to have been laid upon the table, whereas, in connection with so many of the researches that one sees published in the technical papers, as applied to insulating materials, the most important information seems to be kept back, as it were, up the sleeve of the researcher. A work of this kind calls for the attention of a man of more than ordinary abilities, for not only must he be an expert so far as the pottery manufacturing side of the problem is concerned, but he must also have a fundamental knowledge of the electrical factors involved, because, when you are dealing with dielectrics you are dealing with something of which not very much is known theoretically, and the understanding of the behaviour from an electrical point of view of a substance like porcelain is rather difficult to follow out. As can be seen, no very definite statement can be advanced as to the inter-relation between these various tests—puncture tests and what the essayist calls resistivity tests. The resistivity test is a test which a good many people employ because there is nothing very much else to replace it—or at least there has not been much to replace it up to the present time. To my mind the continuous current resistivity test is only of use in so far as it indicates the conductivity of the material under an alternating stress, which, although it is known to be very much larger than the corresponding resistivity as determined by continuous current, yet bears, apparently, under the theory, some relation to it. I think it is very important that the tests should be carried out on materials of known composition and known physical properties, and that the tests should be conducted on the basis of alternating current conductivity. That is rather difficult to carry out, yet I know it is carried out by some electrical firms as an ordinary routine test. I have been an advocate of this test for some time. One of the main difficulties in connection with such a test seems to be this: You may find your insulator hold up quite well under the puncture test so far as you can carry it out, but on the actual insulator you cannot carry your voltage test far enough to break the insulator down, so that, generally speaking, the high voltage is applied as a flash-over test. The voltage is carried up until an arc starts from the pin of the insulator up to the binding wire; this occurs at about three times the normal working voltage of the insulator.

In actual practice it is very doubtful if any material is actually stressed up to anything like those voltages which are given by Mr. Watkin in his paper. In actual practice the insulator, although it fails, is never stressed electrically up to a tenth of that degree which

would cause failure to a sample. It almost appears, therefore, that, with the puncture test, we have to deal with something which is rather different from the conditions which are brought about when dealing with samples. It has been shown, for instance, that under a continuous application of high voltage a sample will alter in its properties, and that alteration, which is what, I believe, must take place in practice when the insulator is erected on the line, can be studied by means of the alternating conductivity test, and has already been studied in connection with materials other than porcelain. In connection with other materials such as those used for cables, the material is continuously subjected to the alternating electrical test, and the conductivity under alternating currents is measured from time to time, and it has been shown that the curve of loss or conductivity proceeds horizontally for a certain length of time, showing no violent increase in conductivity, but that as the temperature rises, the loss increases gradually, until eventually the material breaks down. Now I am fairly sure that the results for dielectric strength do not represent the actual conditions in practice, because they are momentary puncture tests. A more important test, to my way of thinking, but one which is very difficult to carry out in practice—so difficult that the British Electrical Research Association has not been able to carry it out up to the present time—is one under a continuous application of a lower voltage than that which would be required to puncture the material. This is a direction which would offer a very prolific field for research. In saying this I am only trying to show how very difficult it is for any man who starts to work on a problem of this kind to make rapid progress.

With regard to Mr. Watkin's actual results, I think that, from a practical as well as a scientific standpoint, Mr. Watkin's findings must be very interesting to everyone who has done any work of this kind. I am not sure that I quite agree with the very sweeping conclusion which Mr. Watkin has come to, viz:—That this disproves that there is any connection between resistivity and dielectric strength. The action to my mind is a theoretical one, and it has been shown to exist in porous bodies, at any rate where water is present; so much so, that the argument has been frequently advanced that all these dielectric effects are due to water. It can be shown that, with a porous body, when water is present, there is some connection between the alternating conductivity test and the puncture test; and we think that there is some connection between the continous current resistivity test and the alternating test.

To sum up, I think the results which have been put forward by Mr. Watkin are the most interesting set of results that I have ever seen carried out on a dielectric of known composition, and it is very encouraging that they have been carried out on porcelain by a student of the Central School of Science and Technology at Stoke.

I think that the porosity tests are of extreme importance.

Starting with ·016 per cent. of water, the continuous current resistance remained constant after six days' soaking. With ·045 per cent. of absorption there is a fall in the resistivity, but of a constant value; whereas with ·35 it continues to fall and becomes very low. I think I should be correct in saying that, if these had been tried with the puncture test, the only two which would have come out satisfactorily are the first two, viz:—those with ·016 and ·045 absorption. In other words, the application of the continuous current test as well as the porosity test would have separated the sheep from the goats—the good insulators from the bad.

Electrical porcelain is a branch of the pottery industry in which you are probably not all interested, but to those who are interested in this particular branch of the industry the results which Mr. Watkin has given should be found extremely interesting. I personally am much indebted to him for his work, and I should like to take this opportunity of thanking him for the very great help which he has given to the Electrical Porcelain Committee of the British Electrical Research Association. It is only by close co-operation between the pottery manufacturers and the users of their products that substantial improvement can be hoped for, and the whole-hearted co-operation which Mr. Watkin has given to the Association on behalf of his firm has made our work very much easier. I am hoping that, before many years are past, it will be possible for us to publish a certain amount of data that has already been collected, and that it will prove of considerable use to that section of the pottery industry engaged in the manufacture of electrical porcelain.

Mr. C. D. Grimwade:—I would like to ask what were the sizes of the pieces which were tested for high electrical strength. I notice from the table such voltages as 300,000, 320,000 and so forth; but some of us who were privileged in 1912 to see tests that were being carried out at Charlottenburg were assured that it was found extremely difficult to get a pressure of 250,000, owing to the small size of the insulators. After a certain pressure the air was reduced virtually to a conductor and there was a discharge all round the insulator which took no direct path, but seemed to pass freely all round it. I would like to ask how Mr. Watkin managed to overcome this difficulty in the case of small pieces.

Mr. Watkin:—I would like to thank Dr. Ashton for his kind remarks.

The remarks made by Mr. Langton are very interesting, and I am quite in agreement with him when he states that the weakness of porcelain must be sought for in the process of manufacture. Porcelain is an excellent insulating material when thoroughly vitrified and free from flaws—cracks, air pockets, etc. The majority of porcelain insulator failures are attributable to faults incurred during making, drying or firing.

It is essential that the clay be homogeneous in its consistency, and that no unequal or too severe strains are placed upon it during the various processes of making, drying and firing.

Unfortunately, many of the faults are only visible after firing, which means that the faulty article is a total loss. Faults in the interior of the material only make their presence known when the article is subjected to the electric test. The method of manufacture also has a bearing upon the electric strength of the porcelain. My experience is that jollied articles are stronger dielectrically than thrown or cast ones, probably due to the increased pressure used by the jolly.

Replying to Mr. Grimwade, the size of the pieces used in the electric strength tests is shown in Fig. 4., and as stated, the tests were carried out under oil to prevent flashover. The high voltages referred to were not actually obtained, but were calculated from the puncture voltage, and the thickness of the test piece where the puncture occurred.

Mr. H. E. Wood:—There is one point which, amongst others, I was unable to follow. Two bodies, as I understand it, were made up, one with a higher proportion of ball clay than the other at the expense of china clay. This, I understood the essayist to say, gave lower results from the point of view of dielectric strength. I cannot quite see why the sample with the higher amount of ball clay, fired to the same temperature—Cone 8—should break down dielectrically to a greater extent than the one which contained the larger amount of china clay. There is no doubt that the question of complete mixture and homogeneity has a good deal to do with success or otherwise, as also the question of satisfactory firing, but I cannot quite see why the sample with the extra amount of ball clay should have given such bad results. Mr. Langton points out that ball clay is an impure material, but I do not think that the ball clay that we use can be described in that way. It is a perfectly homogeneous material, and it would be quite as well fired up as the sample containing the china clay. Furthermore, there would be no more porosity—in fact, a little less. Perhaps Mr. Watkin can add something to clear up this point.

Mr. Watkin:—The reason why bodies containing ball clay are weaker dielectrically than those containing china clay is that, in ball clay, we have a quantity of organic matter which, during firing, burns out, leaving small pockets, and these cause a bad effect when electrical stresses are applied. If the ball clays could be freed from all their organic impurities, no doubt we should get a body quite as strong dielectrically as a body which is made by using china clay.

XVII.—The Effect of Prolonged Grinding on the Density of Quartz.*

[Communication from the Clay and Pottery Laboratory, Stoke-on-Trent. No. 107].

By A. J. Dale, B.Sc., A.I.C.

THE variation of the density of different modifications of silica as the result of fine grinding has recently been investigated by independent workers.

Ray[1], starting with quartz (silver sand, D. 2·638), subjected it to 15 hours' mechanical grinding in an agate mortar and found its density after this treatment to be 2·528, a *decrease* of 4·17 per cent. He infers this decrease to be due to a 25·7 per cent. conversion of the quartz to the vitreous state (silica glass, D. 2·208). This result bears out a similar conclusion reached by the same author after determining the molecular heats of solution of silver sand in hydrofluoric acid, before and after grinding.

Washburn and Navias[2], finding the low density of 2·175 for calcined chalcedony, redetermined the density of the finely ground material; after grinding in an agate mortar (time not stated), and separating particles of average diameter 0·0023 mms. by suspension in water for 48 hours, they found the density of the powder to be 2·224, an *increase* of 2 per cent. This increase they consider to be due to elimination of submicroscopic pores by grinding.

Johnstone and Adams[3] reporting on the "Density of Quartz of Different Degrees of Fineness," conclude that, if there is a change of density as the result of fine grinding, *it is a decrease.*

Brown, Cook and Warner,[4] note a diminution in the density of crystalline lead oxide after grinding, which decrease is not shown by amorphous lead oxide after similar treatment.

Spring[5], in a series of researches, showed that compression or extrusion caused diminution in the density of substances so different as sulphur, lead, zinc, ammonium sulphate.

Kahlbaum, Roth and Siedler[6], extended these observations to different metals; Grunmach[7], to steel.

Spring[5] suggested that the density changes are due to the assumption of the molecular condition characteristic of the liquid state by these substances. He furthermore showed that pressure accompanied by mechanical deformation can bring about chemical reaction ($CuO+NaHSO_4$) and that a similar result occurs on grinding; he points out that these observations may furnish an explanation of variations in the compositions of certain rocks.

The effect of grinding and abrasion on the crystalline state of aggregation has also received exhaustive consideration in the classical metallographic researches of Beilby[8].

* Reprinted by permission of the British Refractories Research Association, from Bulletin No. 5, December, 1923.

Present Investigation.

An accessory aim of the present work was to test the validity of the conclusions of Ray and of Washburn and Navias, when the possible contamination during grinding is taken into account.

The material under consideration was a sample of vein quartz showing the following composition :—

SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	Loss
99·52	0·12	0·04	0·01	0·16	0·04	0·01	0·14	0·13

In order to reduce the comparatively large pieces of quartz to a size suitable for treatment in the mechanical grinder, they were smashed in an iron mortar ; the finer particles were washed with distilled water through a 20's lawn and freed from iron by magneting and warming with 50 per cent. hydrochloric acid, until the supernatant liquid gave negative results when tested for iron. The product was separated into two fractions by lawning.

	Fraction A.	Fraction B.
	Passed through 20's lawn. Stayed on 60's.	Through 60's, on 100's.
Mean Diameter (Mellor's Mean)	0·456 mm.	0·174 mm.

The work was divided into :—

(1). Investigation of contamination occurring on prolonged grinding in an agate mortar.

(2). Density determination of ground and unground fractions.

(1). *Contamination on Prolonged Grinding.*

The grinding was carried out mechanically, the rate of revolution of the pestle being kept constant throughout these experiments at 120 revs. per min. The weight of the mortar and pestle was taken before and after grinding. Before each weighing, the mortar and pestle were placed in an air bath at 110°C. and cooled in a desiccator over fused calcium chloride, this procedure being repeated until two successive weights checked. Pressure and temperature readings were taken for each weighing, and assuming the air to be half saturated, (an assumption which could only cause an error in the density of the air and in the buoyancy correction of one part in 250), all weights were reduced to vacuo. The balance used for this section of the work was sensitive to 0·005 grm. with a 600 grm. load.

The loss in weight of the mortar and pestle occurring when 3 grms. of Grades A and B respectively were ground for 9 hours are shown below. The dried mortar and pestle were weighed at 3 hour intervals.

Loss in Weight of Mortar and Pestle.

	After 3 hrs.	After 6 hrs.	After 9 hrs.
With Grade A ..	0·065 grms.	0·115	0·240
With Grade B ..	0·160	0·295	0·425

Later determinations, however, showed that the observed loss in weight of the agate mortar and pestle cannot be taken as an absolute quantitative measure of the amount of contamination occurring; *e.g.*, a six hours' grinding of 3 grms of Grade A caused a diminution in weight of 0·175 grms., while a six hours' grinding of 1 grm. of material passing a 100's lawn actually caused a nett increase in weight of the mortar and pestle of 0·025 grms. It was, therefore, concluded that during the grinding, innumerable microscopic holes are cut in the agate face; when the grinding is stopped, some of these minute excavations remain packed with the finely ground powder; continue the grinding and fresh material is forced into the holes and carries on the abrasion.

(2). *The Density Determinations.*

The mean density of the mortar material, obtained by the suspension method in water at 22·8°C., after applying corrections, works out at 2·588 (22·8°/4°).

For accurate density determinations of the finely powdered material, the ordinary type of specific gravity bottle is inadequate.

The excellent "vacuum pycnometer," fully described by Washburn and Navias in their paper "Products of Calcination of Flint and Chalcedony"[2]; was, therefore, resorted to and their method of experimentation followed closely. The method is best described by reference to the diagram of the apparatus.

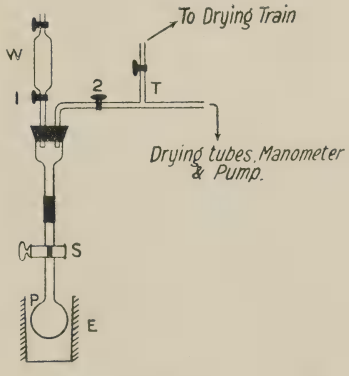

Fig. 1.

The "vacuum pycnometer," *P*, of pyrex glass, could be connected with either a reservoir of air-free distilled water, *W*, *or* with a mercury pump by means of the stop taps shown. Dry air could be admitted to the pycnometer and apparatus through the side tube *T*, and drying train; a small glass drying tower, filled with concentrated sulphuric acid, at the end of this train allowed the rate of inflow of air to be regulated. The drying agent was fused $CaCl_2$,. The pycnometer itself could be heated to and kept

constant at any required temperature up to 400°C. by means of a small wire-wound electric furnace, *E*, run at ordinary lighting voltage with a variable resistance in circuit.

The Weight of the Pycnometer.

Before any determinations were made, the pycnometer was evacuated (1–2 mm.), heated up to 200°C. (1 hr.) and cooled (1 hr.); this procedure was repeated twice. Dry air was then admitted, and the pycnometer (tap *S* closed) was removed to the balance case. The tap was opened momentarily before weighing. The heating and cooling procedure was repeated and the weight again taken. In order to minimise condensation errors during weighing, a similar pycnometer was used as a counterpoise.

The Volume of the Pycnometer.

For this determination, the pycnometer was connected up to the apparatus, exhausted, (1–2 mm.), and filled with water from the reservoir *W*; it was then removed to a thermostat at 22·8°C., the temperature of which could be read to 0·05°C. After two hours the tap, *S*, was closed. The pycnometer was then removed from the bath, any water remaining in the extension above the tap being poured off and the exterior dried. It was left in the balance case overnight before weighing. Two check determinations were taken.

Density Determination and Results.

The material under consideration was admitted to the bulb of the pycnometer through a fine funnel extending through the bore of the stopper. The pycnometer was then evacuated, heated to 200°C., allowed to cool and dry air admitted before weighing. After reconnecting the pycnometer, it was again evacuated and heated to 200°C., tap 2 was then closed and, when the pycnometer was cool, water was admitted by opening tap 1, until the pycnometer was filled to about half way up the extension. The procedure was then the same as in the determination of the volume of the pycnometer. Barometric and temperature readings were taken for each weighing; all weighings were reduced to "vacuo," and the densities corrected for comparison with water at 4°C.=1.

DENSITIES BEFORE AND AFTER GRINDING.

	Unground.	Ground 6 hrs.	Diminution.
Grade A .. 20's to 60's ..	2·6404, 2·6400, 2·6410 } mean 2·6405	2·6353, 2·6347, 2·6349 } mean 2·6350	0·2%
Grade B .. 60's to 100's ..	2·6450, 2·6460 } mean 2·6455	2·6289, 2·6300, 2·6282 } mean 2·6290	0·6%

Grain Size after Grinding.

The ground powders were separated into three fractions by sieving and elutriation, with the following results:—

Mean Diameter of Fraction	0·087 mm.	0·042 mm.	0·0063 mm.	Surface factor
Grade A	2·60%	52·76%	44·64%	189
Grade B	0·80%	50·50%	48·70%	202

Consideration of the Results.

(*a*). *Density of Unground Material.* Considering the densities of the unground material; reduction in grain size of the vein quartz to the extent indicated (Grade A to Grade B) results in a density increase of from 2·6405 to 2·6455 (0·2 per cent.).

It is, therefore, quite permissible to assume that during the grinding of Grade A, its density approaches that of unground Grade B as the mean diameter of A approaches the mean diameter of unground B, *i.e.*, the apparent 0·2 per cent. diminution in density of Grade A caused by a 6 hours' grinding should be at least 0·4 per cent.

(*b*). *Effect of the Agate Contamination on the Density of the Ground Quartz.* We can calculate the effect of admixed agate on the density of the ground quartz, by substituting respective values in the following formula, D_3 being unknown :—

$$\frac{W_1}{D_1} + \frac{W_2}{D_2} = \frac{W_1+W_2}{D_3}$$

where W_1=wt. of quartz ground, and D_1 its original density.

W_2=wt. of agate of density D_2 contaminating qtz. after grinding.

D_3=unknown density of resulting mixture.

(1). Considering Grade A, providing contamination is alone responsible for reduction in density, the density of the ground Grade A should be 2·6436; *i.e.*, contamination of 3 grms. of quartz of density 2·6455, by 0·175 grms. of agate of density 2·588 can account for a reduction in the original density of the quartz of only 0·07 per cent. To cause a reduction in density to the extent observed, agate contamination by at least 0·62 grms. would have to take place.

(2). Considering Grade B, contamination of 3 grms. of quartz of density 2·6455 by 0·295 grms. of agate (maximum loss in weight of mortar and pestle recorded after 6 hrs. grinding) would make the observed density of the powder 2·6401, a reduction of 0·2 per cent.; in order to bring about the recorded reduction in density (0·6 per cent.) agate contamination should amount to 1·18 grms. In both cases, contamination to such a large extent is unlikely; (no marked change in colour was observed during grinding).

Summary.

The effect of prolonged grinding in an agate mortar on the density of quartz has been investigated, and the results obtained show that :—

(*a*) The density of a given sample of quartz is dependent on the grain size of the sample taken.
It is recommended that, for comparative purposes, some indication of grain size should accompany all accurate density determinations.

(*b*) Down to a certain limit in the case of quartz, diminution of grain size causes a slight increase in the density of the material.

(*c*) Prolonged grinding of vein quartz in an agate mortar causes a reduction in density; and this reduction is too great to be accounted for by contamination.

(*d*) If this reduction is brought about by conversion of the crystalline quartz to the amorphous state (silica glass D. 2·208) as suggested by Spring[5] and later by Ray[1], then, in the particular case under consideration, after allowing for agate contamination, the percentage conversion to silica glass works out as follows:—

Grade A	..	1·9 %	.. 6 hours' grinding.
Grade B	..	2·6 %	

(*e*) The percentage conversion is not so large as reported by Ray[1] since he neglected contamination during grinding.

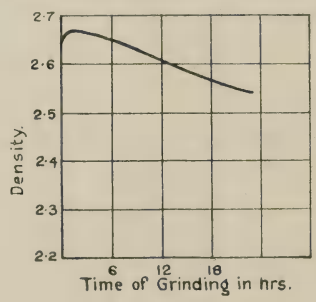

Fig. 2.

The curve relating density of quartz and time of grinding is probably of the form shown. (Fig. 2).

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XVIII.—The Relation between Ordinary Refractoriness, Under-load Refractoriness and Composition, Physical and Chemical, of Refractory Material. Part I.†

[Communication from the Clay and Pottery Laboratory, Stoke-on-Trent. No. 108].

By A. J. Dale, B.Sc., A.I.C.

INTRODUCTION.

The influence of load on the softening point of refractories has been the subject of a considerable number of papers, among which may be mentioned the reports of Mellor and Moore[1], Mellor and Emery[2], and Emery and Bradshaw[3].

The first named authors devised the method at present in use in this country for testing refractory material under load, and arrived at sundry conclusions regarding the behaviour of fireclay and silica materials. A consideration of the following classified results* showing analyses, ordinary refractoriness and the cone at which failure occurs under a load of 50 lbs. per sq. ins., for 62 commercial products, while not leading to any rigid generalisation, affords confirmation of the conclusions previously reached by Mellor and Moore and later by Emery and Bradshaw, that, generally speaking, the more aluminous the refractory, the greater the difference between the normal softening point and the breakdown point under load at high temperatures.

The tabulation which follows is arranged in descending order of silica content. An unsuccessful attempt was made to correlate the SiO_2, Al_2O_3 and total fluxes by means of a triangular diagram.

There appears, however, to be an approximate relationship between the quartz and clay content (from calculated rational analyses) and the difference between the ordinary and under-load refractoriness, such as depicted in Fig. 1 (1 Cone=25°C. Approx.).

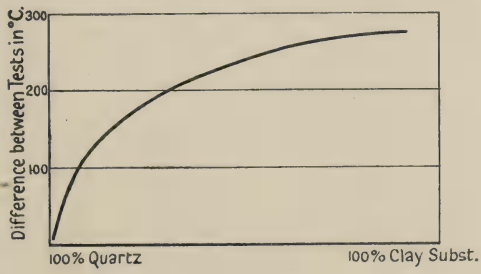

Fig. 1.

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*I am indebted to Dr. J. W. Mellor for these data. Regarding the results of the under-load refractory test, Dr. Mellor states that in these tests, no distinction had been made between a break-down by softening and a break-down by rupture, nor is any account taken of the variations in grain size and proportions of grog, methods of manufacture, etc.

Number	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Loss	Total	Clay	Fels.	Qrtz.	Ferric Oxide	Lime	Ordi'ary Refract.	Under-load	Diff.	Remarks
1	96·67	0·36	0·68	0·50	0·01	1·27	0·08	0·48	0·04	100·09	0·18	3·36	94·85	0·50	1·27	Cones 32-33	29	Cones 3-4	After Expansion 0·15%
2	95·73	Trace	0·66	0·31	0·06	1·96	0·50	1·12	0·06	100·40	nil	9·58	88·16	0·29	1·97	35	29	6	After Expansion 0·15%
3	95·56	—	1·28	0·55	0·02	1·66	0·12	0·74	0·26	100·19	0·87	5·13	91·34	1·27	1·65	33-34	27	6-7	
4	95·42	0·24	0·83	0·65	0·02	2·45	0·60	0·20	0·02	100·43	nil	4·8	92·5	0·65	2·45	32-33	26	6·7	After Expansion 0·06%
5	95·41	0·56	0·81	1·25	—	1·78	0·20	0·26	0·10	100·37	0·9	2·8	93·3	1·25	1·78	32-33	30-31	2	After Expansion 0·12%
6	95·26	nil	0·87	0·45	0·17	2·26	0·70	0·60	0·04	100·35	nil	7·7	89·6	0·4	2·2	33	32	1	After Expansion cone 12, 2 hrs., 0·015%
7	94·90	nil	0·68	0·35	0·20	2·19	0·77	0·42	0·18	99·69	nil	7·14	90·26	0·35	2·19	32	29	3	After Expansion cone 12, 2 hrs., 0·11%
8	94·57	0·43	1·79	0·81	0·12	1·64	0·26	0·30	0·19	100·11	3·0	3·3	91·6	0·8	1·6	32·33	27	5·6	
9	94·48	0·1	1·41	0·53	0·46	2·38	0·70	0·40	0·12	100·48	0·6	6·6	89·9	0·5	2·4	31	30	1	No changz, Cone 12, 2 hrs.
10	93·2	0·15	1·07	0·78	0·10	3·80	0·30	0·12	0·10	99·62	1·55	2·5	91·0	0·7	3·8	32-33	31	1-2	After Expansion 0·12%
*11	92·90	nil	2·37	1·50	0·16	1·28	1·10	0·68	0·04	100·03	1·12	10·68	88·44	1·50	1·28	33-34	15	13-14	
12	91·95	1·54	1·96	0·63	0·23	3·04	0·58	0·58	0·08	99·59	1·8	7·0	87·1	0·6	3·0	32	20	7	
13	91·82	nil	3·44	0·94	0·05	2·51	0·66	0·50	0·15	100·07	5·4	6·9	83·9	0·9	2·5	33-34	18	10-11	
14	88·98	0·60	7·59	0·72	0·13	0·88	0·58	0·46	nil	99·94	15·9	6·2	76·3	0·7	0·9	34	14	15	After Expansion 0·53%
15	84·10	0·83	11·78	1·95	0·11	0·34	0·28	0·70	0·14	100·23	25·8	5·7	66·4	1·9	0·3	26-27	14	7-8	

Number	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Loss	Total	Clay	Fels.	Qrtz.	Ferric Oxide	Lime	Ordi'ary Refract.	Under-load	Diff.	Remarks
16	83·27	1·21	11·23	0·87	0·39	0·77	1·04	0·42	0·32	99·52	23·67	8·58	66·26	0·85	0·75	26	16	5	After Expansion Cone 14, 2 hrs., 0·09%
17	82·98	0·72	12·3	2·5	0·28	0·26	0·82	0·46	0·14	100·46	26·5	7·3	63·7	2·3	0·2	20-26	13-14	7	
18	81·16	1·04	14·80	0·81	0·08	0·80	1·00	0·60	nil	100·27	31·2	9·2	58·0	0·77	0·76	30	18-19	6-7	After Expansion 0·135%
19	79·36	1·52	15·35	1·75	0·14	0·98	0·74	0·56	gain 0·07	100·4	33·17	7·42	56·89	1·66	0·93	28	16	7	After Contraction 0·02%
20	79·36	0·63	16·05	2·19	0·27	0·21	0·98	0·22	0·20	100·11	26·7	7·2	58·4	2·19	0·21	30	14	11	After Expansion 0·09%
21	78·90	0·71	16·14	1·87	0·13	1·02	0·88	0·46	0·20	100·31	34·9	7·6	54·6	1·8	0·9	29	17·18	6·7	After Expansion Cone 12, 2 hrs., 0·26%
22	77·75	1·04	18·32	1·25	0·14	0·29	1·00	0·50	0·20	100·49	39·38	8·48	50·68	1·18	0·28	30	19	6	After Contraction 0·25%
23	77·10	1·32	18·59	1·66	0·25	0·30	0·46	0·42	0·16	100·26	44·1	5·28	54·54	1·66	0·3	29	14·15	9-10	
24	75·76	0·99	18·91	1·75	0·04	0·80	1·12	0·36	0·38	100·11	40·9	8·4	48·2	1·7	0·8	31-32	15-16	11	
25	74·69	0·62	21·37	1·01	0·17	0·41	1·14	0·58	0·18	100·17	45·63	9·64	43·24	0·94	0·41	30	19	6	After Contraction 0·075%
26	74·03	0·63	23·17	0·93	0·01	0·01	0·51	0·41	0·01	99·68	51·73	5·08	42·41	0·86		31	19	7	After Contraction 0·17%
27	73·60	1·11	20·55	1·88	0·36	0·24	1·16	0·42	0·20	99·52	45·1	8·1	44·8	1·8	0·2	28	17	6	
28	73·14	1·16	22·9	1·51	0·05	0·29	0·64	0·34	0·19	100·22	50·75	5·46	42·1	1·4	0·3	32·33	15-16	12	After Contraction nil.
29	71·03	1·00	23·99	1·64	0·06	0·49	0·96	0·32	0·19	99·78	52·2	7·1	38·9	1·5	0·5	31	18	8	After Contraction 0·26%

Number	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Loss	Total	Clay	Fels.	Qrtz.	Ferric Oxide	Lime	Ordi'ary Refract.	Under. load	Diff.	Remarks
30	70·23	1·19	23·77	2·56	0·30	0·22	1·16	0·42	0·20	100·05	55·3	9·5	39·8	2·6	0·2	26-27	14-15	7	After Contraction 0·07%
31	68·86	1·46	24·92	2·66	0·38	0·60	0·86	0·48	0·22	100·44	54·3	7·3	35·2	2·5	0·6	30	14	11	No change. Cone 12, 2 hrs.
32	66·86	1·25	26·65	2·69	0·28	0·28	0·18	0·40	0·16	99·75	62·3	9·5	33·3	2·69	0·28	29	16	8	After Contraction 0·72%
33	65·20	1·51	29·54	0·75	—	0·37	0·94	1·74	0·25	100·30	60·89	14·70	23·35	0·33	0·68	32	14	13	After Contraction 0·72%
34	63·56	1·56	29·92	2·25	0·25	0·55	1·02	0·59	0·24	99·94	64·42	8·83	24·17	2·05	0·50	29-30	13-14	11	
35	62·62	1·33	27·44	3·59	0·21	0·33	3·52	0·76	0·39	100·19	52·65	23·91	19·78	3·34	0·30	29-30	16	8-9	After Contraction 1·62%
36	61·76	1·66	31·43	1·51	trace	1·18	0·62	1·62	0·44	100·22	65·94	11·86	19·38	1·37	1·07	30	14	11	After Contraction 0·30%
37	61·55	1·47	29·26	2·81	0·12	1·00	1·64	1·20	1·34	100·39	60·09	15·76	20·17	2·62	0·92	19	11-12	7-8	
38	61·26	1·35	31·63	1·56	0·25	0·92	1·84	0·94	0·30	100·05	65·3	15·2	17·2	1·4	0·9	30-31	14-15	11	
39	61·22	1·72	32·81	1·81	—	0·63	0·66	0·32	0·43	99·60	71·96	5·33	20·49	1·70	0·60	31-32	16	10-11	After Contraction nil.
40	59·90	2·27	34·77	1·50	0·25	0·20	0·94	0·38	0·20	100·41	83·38	7·92	18·31	1·50	0·20	33	20	8	
41	59·80	1·38	36·12	1·09	0·25	0·40	0·60	0·46	0·06	100·16	87·5	6·4	16·8	1·09	0·40	32	26-27	5-6	
42	59·74	1·79	34·07	2·34	0·37	0·30	1·06	0·28	0·24	100·19	81·55	8·04	18·79	2·34	0·30	30-31	16	9-10	
43	58·94	1·51	32·89	1·72	1·21	0·86	1·56	0·78	0·40	99·87	69·7	12·9	15·1	1·6	0·8	30-31	16-17	9	
44	58·78	1·31	31·98	5·31	0·60	0·54	0·78	0·66	0·12	100·08	69·1	7·8	17·7	4·8	0·5	29-30	14	10-11	After Contraction 0·17%
45	57·72	1·47	36·11	2·81	0·46	0·36	1·00	0·30	0·06	100·29	86·7	7·8	14·3	2·81	0·36	31	16-17	9-10	After Contraction 0·27%

Number	SiO_2	TIO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Loss	Total	Clay	Fels.	Qrtz.	Ferric Oxide	Lime	Ordi'ary Refract.	Under-load	Diff.	Remarks
46	57·45	1·92	36·05	2·44	0·25	0·64	0·50	0·52	0·17	99·94	78·24	5·48	13·60	2·18	0·57	32-33	16-17	11	After Contraction nil.
47	57·28	1·67	36·28	2·56	0·34	0·48	0·94	0·58	0·20	100·33	86·7	9·1	12·7	2·56	0·48	32	17-18	9-10	
48	56·62	1·92	38·55	1·40	0·32	0·30	0·70	0·20	0·18	100·19	94·0	5·4	11·8	1·4	0·3	32-33	19	8-9	After Contraction nil.
49	56·00	1·25	37·00	2·19	0·51	0·64	1·84	0·68	0·20	100·31	76·9	13·5	7·0	1·9	0·6	33	18	10	
50	55·08	1·43	37·48	3·44	0·31	1·51	1·31	0·39	0·20	100·15	79·5	9·1	7·9	3·1	0·5	31	17	9	
51	54·93	1·72	37·25	3·75	0·64	0·72	0·88	0·38	0·26	100·03	79·97	6·73	9·49	3·34	0·64	30	17	8	
52	54·52	2·00	37·66	3·44	0·47	0·28	1·04	0·32	0·23	99·96	90·48	8·16	9·60	3·44	0·28	32·33	17-18	10	
53	53·78	3·40	39·57	1·75	0·06	0·18	0·60	0·52	0·14	100·00	84·5	5·9	7·5	1·7	0·2	33-34	19	9-10	After Contraction nil.
54	53·34	2·50	40·85	1·60	0·04	0·62	0·50	0·64	0·21	100·30	99·0	6·8	5·8	1·6	0·6	34	29	5	
55	52·79	2·50	30·93	1·33	0·81	0·63	0·98	0·32	9·99	100·28	73·8	7·8	16·3	1·33	0·6	31-32	14	12-13	
56	52·62	1·34	41·59	2·10	0·24	0·41	0·66	0·68	0·24	99·85	88·5	7·1	2·4	1·8	0·4	33-34	17-18	11	
57	52·46	1·24	40·65	3·27	0·37	0·78	0·41	0·72	0·18	100·08	86·90	5·97	3·51	2·88	0·69	>35	17	>13	
58	52·00	3·00	41·66	1·88	0·22	0·24	0·40	0·52	0·24	100·16	89·6	4·8	3·6	1·8	0·2	35	18	12	
59	51·40	2·06	42·32	1·32	0·27	0·52	0·88	0·50	0·28	99·55	90·04	7·35	1·02	1·16	0·45	>35	26	>9	After Contraction 0·35%
60	51·20	3·50	41·66	1·88	0·15	0·30	0·80	0·18	0·20	99·87	101·50	5·88	3·66	1·88	0·30	34	18	11	
61	51·02	2·50	43·52	2·00	nil	0·2	0·42	0·50	0·14	100·30	92·1	4·8	1·1	1·7	0·1	34	16-17	12-13	No Change Cone 14, 2 hrs.
62	50·64	1·30	42·44	3·33	0·50	0·92	0·32	0·62	0·29	100·36	90·75	4·93	0·53	2·92	0·81	35	29	6	

The figures in the column headed Diff. show the difference in Cones between the Ordinary and U.L. Refractoriness.
Cone 20 to 26 is regarded as a one cone interval.

This is to be expected since the quartz-clay ratio is dependent to a large extent on the SiO_2 content.
(Results of a further consideration of these data will be included in a later report).

Underload Refractory Test. Present Procedure.

The present method of carrying out the refractory test under load is described in a previous paper by Mellor[4]. In practice, the material being tested is usually reported as failing under a known load, at that cone which has just fallen when the test piece itself has undergone a subsidence of 7/12″; generally speaking, this degree of subsidence does not take place until complete failure at the test piece has occurred. The result of the test, therefore, marks the temperature (in cones) of complete failure.

Furnace Modifications

At the onset of this work, the external fittings of the present type of furnace were modified, at Dr. Mellor's suggestion, with a view to

(*a*) Ensuring verticality of the applied load, and eliminating the possibility of shearing forces acting on the test piece.

(*b*) Enabling the behaviour of a refractory, under load at elevated temperatures, to be followed.

The modified furnace is illustrated in Fig. 2.

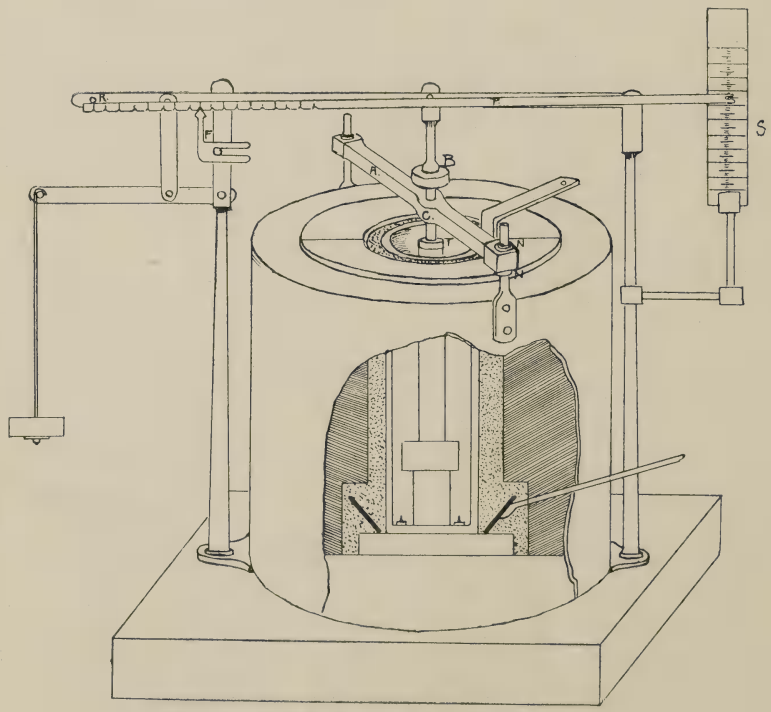

Fig. 2. Modified Under-load Test Furnace.

The additions to the furnace consist of :—

(1) A vertical collar *C* drilled through a horizontal arm *A* ; by means of adjusting nuts, *N*, at the extremities of this arm, the short thrust rod, *T*, passing through the collar is easily and rapidly adjusted to a vertical position.

(2) A cup and ball arrangement at *B* for the transference of the thrust from the main lever arm to the thrust rod.

(3) A graduated, notched aluminium rod, *P*, 42″ long, supported on a moveable knife-edge fulcrum, *F*. Cross wires placed in a slot at the extremity of this rod move over a scale, *S*. By means of this arrangement, vertical movement of the test piece (and supports), heated under load, may be recorded with a magnification of from 10/1 to 40/1, according to the position of the fulcrum and the relative lengths of the recorder arms.

EXPERIMENTAL.

Fireclays with Fireclay Grog.

As has been indicated in an interim report, in order to extend the pioneer work to which reference has already been made, it has been considered advisable to commence this investigation with a detailed examination of products made in the laboratory from a selection of the refractory clays of this country, the methods of making, grog preparation and grading, and firing being effected in a comparable manner.

The results obtained from five series of experimental bricks are accordingly presented in this paper which may be regarded as preliminary and indicative of the directions in which the problem is being attacked.

Detailed discussion is avoided at this stage of the work.

Grog Preparation and Grading.

Grog was prepared from the clay with which it was to be used, moulded in small pieces, dried and subjected to two china-biscuit firings, ground in a jaw-crusher and separated into four fractions. In all the work included in this report, a constant grog grading was used, viz. :

Thro' 4's on 8's.	Thro' 8's on 16's.	Thro' 16's on 30's.	Thro' 30's.
30%	30%	30%	10%

Mixing, Moulding, etc.

Mixing and tempering were carried out by hand, and the briquettes were slop-moulded in a wooden mould. From each clay used four sets of briquettes were prepared, viz. :

(1) Straight Clay.
(2) 20% grog content.
(3) 40% grog content.
(4) 60% grog content.

Firing.

The whole of the test bricks were fired in a commercial kiln to a temperature corresponding to cones 13-14.

Determinations.

(1) Ultimate chemical composition and calculated rational analysis.
(2) Relative grain-size composition of raw clays expressed as surface factors.
(3) Porosity and apparent specific gravity.
(4) True specific gravity.
(5) Contractions on drying and firing.
(6) Refractoriness. In cases of doubt, this test was carried out in duplicate.
(7) Behaviour under load at high temperatures.

ANALYSIS OF RAW MATERIALS.

Clay Lab. Mark	*S*	*B*	*C*	*M*	*A*
Silica (SiO_2)	64·30	50·25	47·56	46·39	43·40
Titanic Oxide (TiO_2)	1·32	0·91	—	1·58	3·35
Alumina (Al_2O_3)	21·34	33·26	38·50	36·26	36·89
Ferric Oxide (Fe_2O_3)	1·88	1·62	0·62	1·59	0·69
Magnesia (MgO)	0·51	0·22	0·03	Trace	Trace
Lime (CaO)	0·34	0·63	0·29	0·56	0·78
Potash (KO)	1·02	2·66	1·32	0·50	0·50
Soda (Na_2O)	0·084	0·50	0·10	0·60	0·26
Loss	8·9	9·79	12·02	13·93	14·1

CALCULATED RATIONAL ANALYSIS.

Clay	60·0	75·5	90·5	81·6	93·5
Felspar	6·5	18·6	8·3	7·2	4·9
Quartz	36·4	3·1	nil	8·9	nil
Ferric Oxide	1·88	1·62	0·62	1·6	0·69
Lime	0·34	0·63	0·29	0·56	0·78
			Excess Al_2O_3		Excess Al_2O_3

Grain Size Analyses of Raw Clays.

The raw clays as used, *i.e.*, ground to pass a 20's sieve, were separated into four fractions by sieving and elutriation. The velocity of the water flow during elutriation was calculated to carry away particles of diameter ·01 mms. In each case 10 grms. of raw clay were shaken mechanically for 6 hours in water rendered just alkaline by addition of a few drops of NH_4OH. The weights

of the various fractions obtained are given below, together with the calculated surface factor[2].

	Stays on 120's lawn	Passes 120's on 200's	In Elutriator	Carried over	Surface factor
Mean diameter	0·423 mm.	0·087	0·042	·0063	
S ..	·96	·45	2·39	8·20	237
B ..	·537	·793	3·705	4·92	198
C ..	nil	·15	1·46	8·39	309
M ..	5·18	0·86	1·87	2·19	93
A ..	5·35	0·93	1·74	1·98	85

PHYSICAL DATA.

	% vol. contraction (*a*) Wet—dry (*b*) Dry—fired		True sp. gr.	App. sp. gr.	% Porosity
	(*a*)	(*b*)			
S. Straight clay ..	21·81	34·06	2·47	2·06	14·79
S. 20% grog ..	16·69	23·90	2·55	1·87	26·73
S. 40% ,, ..	7·08	12·84	2·56	1·72	32·28
S. 60% ,, ..	6·80	—	2·55	1·72	32·01
B. Straight clay ..	29·45	50·98	2·40	2·37	1·14
B. 20% grog ..	18·35	40·65	2·40	2·17	9·94
B. 40% ,, ..	17·74	26·80	2·46	1·92	21·84
B. 60% ,, ..	8·20	14·37	2·47	1·82	27·01
C. Straight clay ..	11·69	34·87	2·58	1·98	21·8
C. 20% ,, ..	6·10	31·39	2·69	1·74	35·47
C. 40% ,, ..	1·80	20·20	2·73	1·61	40·35
C. 60% ,, ..	—	16·70	2·71	1·61	40·49
M. Straight clay ..	11·94	18·32	2·68	2·19	21·64
M. 20% grog ..	11·95	6·41	2·65	1·91	27·71
M. 40% ,, ..	4·46	2·33	2·65	1·80	33·53
M. 60% ,, ..	very low		2·63	1·71	34·09
A. Straight clay ..	9·82	30·08	2·75	2·03	26·10
A. 20% ,, ..	6·12	7·81	2·75	1·72	37·32
A. 40% ,, ..	3·14	3·12	2·73	1·60	40·10
A. 60% ,, ..	very low		2·73	not detd.	not detd.

ORDINARY REFRACTORINESS.

Raw Materials.

	S	*B*	*C*	*M*	*A*
Cones ..	29	30	>35	33	>33/34
°C.	1650	1670	>1770	1730	>1740

FIRED PRODUCTS. (Cones and Approx. °C.).

Grog	*S*	*B*	*C*	*M*	*A*
Straight .. clay ..	30 1670°	31 1690°	>35 >1770°	32 1710°	>35 >1770°
20%	29 1650°	31-32 1700°	>35 >1770°	32 1710°	>35 >1770°
40%	29 1650°	32 1710°	>35 >1770°	32-33 1710°	>35 >1770°
60%	29 1650°	32 1710°	>35 >1770°	33-34 1740°	>35 >1770°

BEHAVIOUR OF EXPERIMENTAL MATERIALS UNDER LOAD AT ELEVATED TEMPERATURES.

It was decided, in order to obtain results comparable with those previously tabulated in the introduction to this report, to proceed with the underload test as at present carried out, following the movement of the test pieces from the temperature at which thermal expansion ceases until rapid subsidence developes.

In the curves of Series 1, Figs. 3 to 7, which follow, linear changes of the test piece beyond this temperature are plotted against temperature, indicated by cones, the heating being stopped when the test piece has undergone a subsidence of approximately $\frac{1}{2}''$. Except in the case of the C briquettes, this range of subsidence included the point of complete failure.

With reference to Figs. 3 to 7, the abscissæ represent cone temperatures. The centigrade temperatures should be deleted and the corresponding cone temperatures inserted. (c.f. standard cone-temp. table).

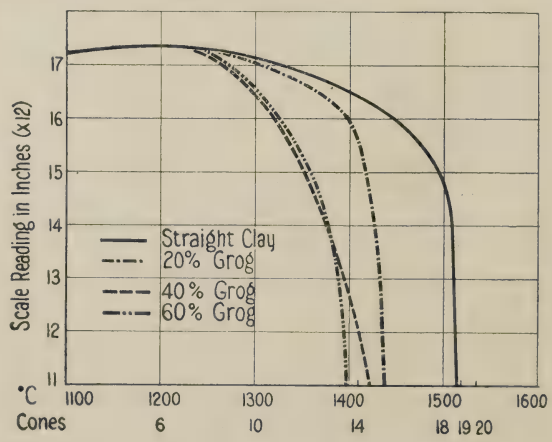

Fig. 3. Series I. *S*.

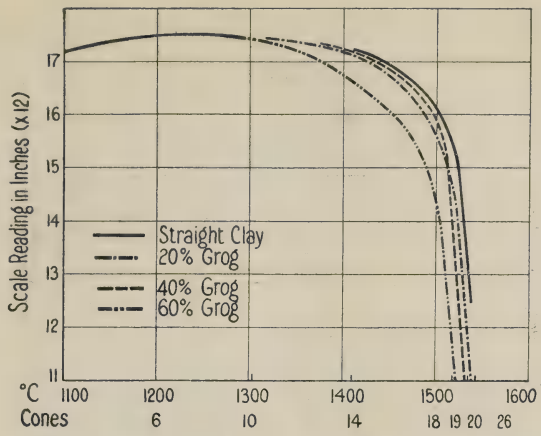

Fig. 4. Series 1. *B*.

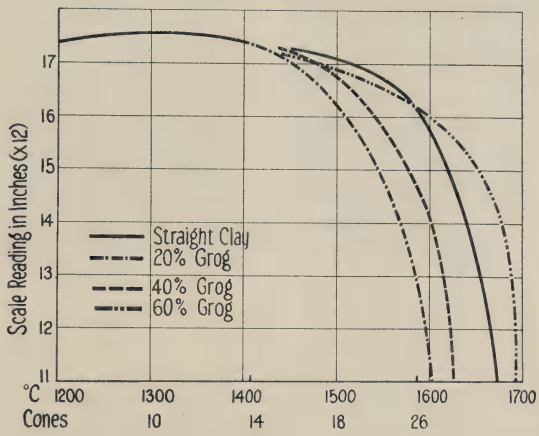

Fig. 5. Series 1. *C*.

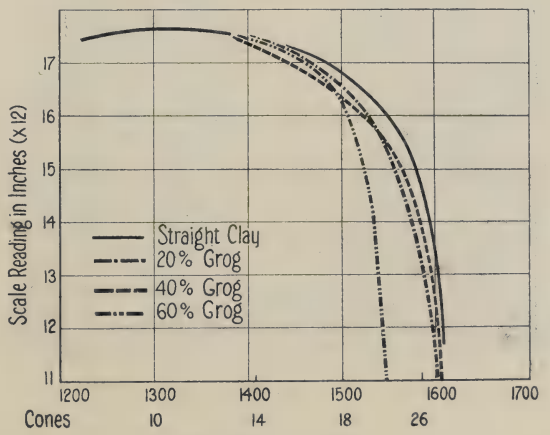

Fig. 6. Series 1. *M*.

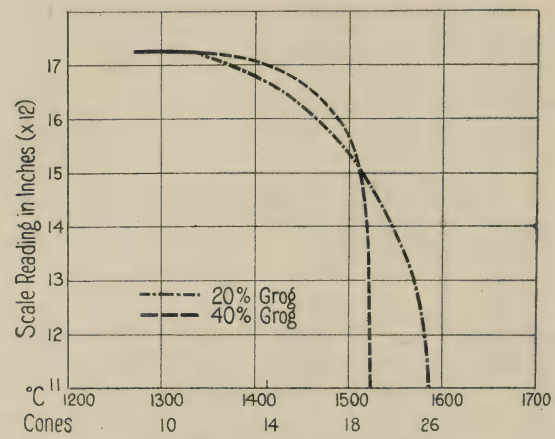

Fig. 7. Series 1. *A*.

Three conclusions are arrived at from a study of these curves, viz. :—

(1) For a specific clay heated up under a constant load, the temperature at which subsidence commences is independent of the grog content.

(2) With the refractories examined, there is a variable range of temperature between the commencement of the under-load subsidence and the point of complete failure.

(3) With one exception (C 60 per cent. grog), the temperature at which complete breakdown underload occurs is lower with the grogged bricks than with the straight clays.

Mechanism of Breakdown Under-load.

From an examination of the various pieces after the test, it

Fig. 8.

is concluded that the breakdown of refractory material under-load at high temperatures may occur in one of three ways.

(*a*) Straight subsidence. No bulging of test piece. Appears to be an absolute volume contraction. This type of subsidence occurred with the whole of the *C* bricks, which had been shown to possess comparatively high porosities. Fig. 8.

(*b*) Subsidences with bulging of sides of piece accompanied by actual cleavage. Shown by the *B*, *S*, and *M* straight clays; the *S* 20 per cent. grog; and the grogged *M* and *A* pieces. Fig 9.

Fig. 9.

(*c*) Subsidence accompanied by a diagonal plane of cleavage, similar to the type of break occurring with cast iron and timber tested to the breaking point under compressive stress.

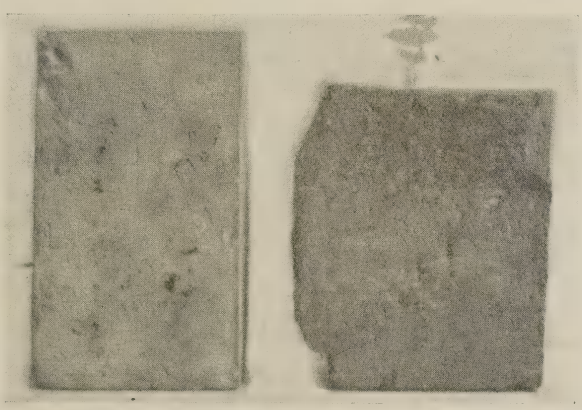

Fig. 10.

The cleavage plane is inclined at about 45° to the horizontal. Obviously some softening has occurred, for the two portions of the test piece hold together, although in some cases the top portion is displaced laterally to the extent of $\frac{1}{8}''$; shown by the *B* and *S* grogged pieces (except *S* 20% grog). Fig. 10.

Behaviour of Refractory Material under-load at a Fixed Temperature.

Considering any one of the curves of Series I. it is not permissible to conclude that the subsidence which has occurred when a certain temperature is reached is a measure of the subsidence which would take place if the piece were subjected to prolonged heating at that temperature. It is almost certain that the progress of the change preceding collapse is dependent not only on temperature itself, but also on the time of heating. In order to obtain quantitative data concerning linear changes of refractory material under a known load at some fixed temperature the under load test procedure was followed until a temperature within the subsidence range of 1,350°C. was attained. Then by use of a variable carbon biscuit resistance, it was comparatively simple to keep the temperature at this value for any required time.

It was further foreseen that the modifications fitted to the furnace, and already described, opened up the possibility of the complete examination of the behaviour of a refractory under load at a fixed temperature in so far as it might be possible to obtain

(*a*) A general indication of the progress of thermal expansion under load.

(*b*) A more exact determination of the temperature at which thermal expansion under-load ceases.

(*c*) An indication of the temperature range in which the dimensions of the refractory, under the load test, remain more or less constant.

(*d*) An indication of the temperature at which subsidence under load commences.

(*e*) A measure of the subsidence occurring under load at a fixed temperature (1,350°).

(*f*) By measuring the length of the piece before and after the test, (cooled slowly overnight), by means of vernier calipers, a determination of what may be termed "after contraction under load."

It would only be possible, with the present type of furnace, to make an absolute determination of the thermal expansion under load if the thrust-rod and supports could be kept at a constant temperature throughout the test, or expanded by a known amount for a known test-piece temperature. Whilst neither of these ideal conditions has, as yet, been attained, it has been found possible to prepare a standard test-piece and thrust-rod which show a

regular thermal expansion up to a test-piece temperature of 1,400°C. Furthermore, the vertical dimensions of this standard test piece and thrust-rod remain almost constant at this temperature for a prolonged period (3 hours).

Preparation of Standard Test Piece and Thrust-Rod.

The preparation of the standard test-piece was finally effected by subjecting a *C* clay briquette to three successive firings, under a load of 75 lbs. per sq. inch, to a temperature of cone 26 down. The cylinders comprising the thrust-rod were treated in a similar manner. Both the carborundum block, placed immediately above the test-piece, and the commercial carbon brick upon which the test-piece rests had been in use in another furnace for some considerable period.

Standard Reference Curve.

A preliminary experiment was carried out with the specially prepared carborundum thrust-rod cylinders extending from top to bottom of the furnace. This rod, subjected to a load of 50 lbs. per sq. inch and a 2 hours' heat-soaking at a temperature of 1,300°C. at the test-piece zone, showed negligible contraction. A further experiment carried out with the standard test-piece, heated under a load of 50 lbs. per sq. inch to a temperature of 1,400°C., showed a regular thermal expansion. Furthermore, the linear dimensions in a vertical direction remained practically constant during a three hours' heat-soaking at this temperature.

The results of this determination were plotted, linear changes as ordinates, and temperature and time as abscissæ, and are recorded in the standard curve (see graph Series II., Fig. 11). The behaviour of other refractory material under load at high temperatures may be compared with this curve.

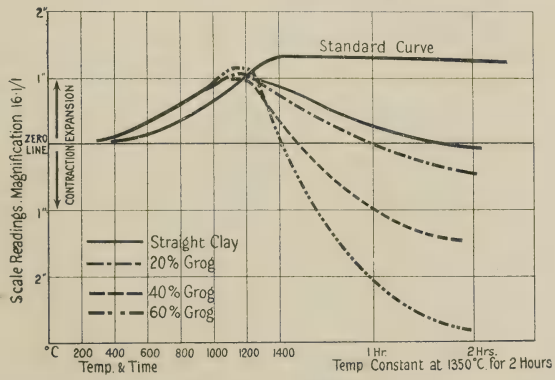

Fig. 11. Series II. *S.*

Discussion of S Curves of Series II.

Having formulated a standard reference curve, an investigation

of the behaviour of the S, *B*, *C*, *M*, *A*, straight clay and grogged briquettes, at 1,350°C. under a static load of 50 lbs. per sq. ins., was undertaken.

Temperature readings were obtained by the use of a standardized Pt. Pt. Rh. couple, the hot junction being kept in contact with the centre of one face of the test piece.

The reults obtained with the *S* series are appended (graph Series II, Fig. 11), as indicating the scope and general utility of this method of investigation.

Temperature Gradient of Thrust-Rod.

In order to limit the unknown factors as far as possible, the temperatures of the cylinders comprising the thrust-rod, one hour after the test piece had assumed a temperature of 1,350°C., were taken.

TEMPERATURE GRADIENT OF THRUST-ROD.

	Standard Piece		Straight *S*	*S* 20% grog	*S* 40% grog	*S* 60% grog
	(*a*)	(*b*)				
Top of carborundum block..	1210°C.	1200	1210	1210	1200	1230
Middle bottom cylinder ..	1190	1195	1185	1200	1180	1220
,, 2nd ,, ..	1120	1100	1105	1130	1100	1130
,, 3rd ,, ..	990	990	990	1005	970	1030
,, 4th ,, ..	810	825	825	810	830	850
,, 5th ,, ..	630	640	655	620	660	640
,, top ,, ..	450	450	420	420	430	440

The curves in Fig. 11 are therefore strictly comparable.

LENGTH OF PIECES BEPORE AND AFTER TEST (in cms.).

	Straight *S*	*S* 20%	*S* 40%	*S* 60%
Before Test	8·974	9·12	9·01	9·205
After Test	8·830	8·92	8·76	8·735
After contraction under load	1·60%	2·19	2·65	5·160

Comparative Contractions at 1,350°C.

The following figures are obtained from the graph, and must be understood to indicate only comparative contractions occurring at 1,350°C. They are to be distinguished from the "After Contractions under Load" recorded in the above tabulation, which are equal to the subsidence occurring at 1,350°C., *plus* a further subsidence taking place during cooling.

From a study of the curves of series II *S*, there is evidence that, for a clay of the *S* type, the rate and amount of subsidence under load at a fixed temperature is related, within limits, to the proportion of grog, *i.e.*, the greater the proportion of grog, the more rapid the subsidence and the greater its amount.

CONTRACTIONS AT 1,350°C. (COMPARED WITH BEHAVIOUR OF STANDARD PIECE AT 1,350°C.).

	Straight *S*		*S* 20% grog		*S* 40% grog		*S* 60% grog	
	cms.	ins.	cms.	ins.	cms.	ins.	cms.	ins.
Comparative contraction at 1350° for 2 hrs.	0·20	0·08	0·28	0·11	0·44	0·17	0·64	0·25

The remaining curves of series II will be presented in Part 2 of this report, together with the results of a complete examination of a typical selection of commercial firebrick products.

References:
(1) J. W. Mellor and B. J. Moore, *Trans. Inst. Gas Eng.*, 1916, 70.
(2) J. W. Mellor and W. Emery, ibid., 1918, p. 71.
(3) W. Emery and L. Bradshaw, Ibid., 1919-20, p. 93.
(4) L. Bradshaw and W. Emery, Ibid., 1920-21, p. 326.
(5) J. W. Mellor, Standardisation of Tests, Ibid., 1918.
(5) J. W. Mellor, *Trans. Cer. Soc.*, 9, 106, 1910.

XIX.—Sedimentation as a Means of Purifying Clay.*

[Communication from the Clay and Pottery Laboratory, Stoke-on-Trent. No. 109].

By S. R. Hind, B.Sc., A.R.C.Sc., A.I.C.

1.—INTRODUCTION.

In no section of ceramic work can we be said to suffer from a more lamentable lack of real knowledge than in that dealing with the ultimate physical nature of clay. Thus it follows that our processes for bringing fireclays and clays in general into that state which is most suitable for their firing and utilisation in industry, are based largely on laborious and expensive trial-and-error methods. The method of treatment which suits one clay will give hopelessly imperfect results with another. Why this is so, we can only at the best make a shrewd guess. Again, a process of manufacture may work excellently for a long time with a given clay and then, for some unknown reason, trouble will crop-up—and such serious trouble as to cause grave loss—and yet the cause of it is rarely traced. Various methods are tried and at last one may be found which cures the trouble, or the difficulty may disappear, to crop up another day. But the curative measure, and the "explanation," if any, based upon it, are almost always of a rule-of thumb nature, unexplained in terms which have any absolute significance. No doubt this can largely be accounted for by the complicated nature, physical and chemical, of the material with which we have to deal. Complete chemical analyses often take so long to get that they are practically useless in the face of a works difficulty. And these give only one aspect of the case. No method is in existence of determining rapidly and accurately the value of physical properties, such as plasticity, on which we feel so much depends. We are not able, without direct recourse to experiment, to say how much a piece of clay will contract on drying (much less the effect of firing upon it), or how much of a given grog or other non-plastic material it will satisfactorily hold together, no matter how many of its other characteristics we are supplied with. This means that we have not got full control of our material; that expensive troubles will continue to arise until we are in a position, by means of rapid and quantitative tests, to say exactly what our raw clay *is* at any time, and so to allow for this, that *preventative* measures can be put in hand *at once*, and the product maintained uniform and of the highest quality at all times.

The subject of the purification of clay, then, assumes a greater rôle in the scheme of things than that of making certain low-grade

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clays into good refractories or highly-bonding materials. It affords means of attack which, if properly worked out and logically dealt with, must go far to solving the mystery of the ultimate physical nature of plastic materials like clay. The author of this paper cannot claim to have gone any great distance along this road, nor even to have completed this programme; delays and other duties have suspended this work for the time being. It is thought how-, ever, that the facts and ideas incorporated in this report will at least help to clear the ground for future progress.*

2.—SOME LABORATORY TESTS AND FUNDAMENTAL CONSIDERATIONS.

In working with mixtures of clay and water where there is sufficient water to give a thin slip or suspension, several things soon become obvious. In the first case, though the clay is apparently not the least bit soluble in the water, it will remain suspended for hours, and under certain conditions a portion will not settle out after years of standing. This portion gives the water a brownish or bluish tinge and the particles are so fine that they exhibit vigorous movement when viewed under the microscope. These particles (large particles show the same effect to a less degree as their size increases) are of colloidal dimensions, *i.e.*, their diameters vary, according to Zsigmondy, from 10 millionths (10^{-5}) to a ten-millionth (10^{-7}) of a centimetre, the lower limit of which is not far from the size of a truly soluble molecule, such as cane-sugar. But in addition to these particles, which may form only a minute percentage of the clay, other particles, less permanently suspended, range throughout all sizes to those which can be removed by ordinary sifting or lawning operations.

Clays, however, as naturally occurring, contain numerous impurities, of which silica grains, pyrites, micas, and felspars are usually the most prominent. These may occur in particles of the same size as the clay-grains, but usually, by far the greater part occur in grains so much larger than those of the clay, that it is possible to allow them to settle out and so obtain a clay of much greater purity, higher refractoriness, and greater plasticity and binding-power. This process is largely adopted in the preparation of china clay for the market. This material occurs naturally, often with three times its weight of undesirable matter, and yet, when suitably treated by settling, a material is obtained which is one of the purest known forms of clay.

A reference to the analyses of ordinary sedimentary clays will show that these are frequently of a higher degree of purity than the natural china clay *rock*, often showing 75 per cent. of clay substance or more. This is due to *natural* washing and it is only reasonable

*A great deal of work not incorporated in this report has been done by Mr. Hind: it is, however, at present filed in the archives of the British Refractories Research Association.

to suppose, that if this process could be carried to completion, artificially, a vast store of very pure and at the same time highly plastic clay would be at our service.

At this point it is perhaps as well to notice that all deposits of clay are not equally well adapted to purification in this way. There are certain valuable fireclays which do not consist of particles of anything approaching colloidal dimensions. The American flint clays, for instance, would scarcely be an attractive proposition for purification by settling. Again, there are clays which contain a high proportion of small grains, as nodules, which are as pure as, if not purer, than the general run of the material. Several well-known fireclays are, to the writer's knowledge, of this nature. Sedimentation of such clays would give rise, in any case, to a heavy loss of material, and much of this would be of a valuable refractory nature. That such deposits of clay are not promising as raw material for the preparation of a specially pure, highly bonding clay need not concern us greatly, as these clays are already of such refractoriness and monetary value that the margin of improvement on both scores is low. What we are more concerned with utilising are surface clays and shales, such as are commonly used for brick-making and the less stringent uses to which refractories are put.

Now if we take a material of this kind we may find it either plastic or shaley. In the latter case it may only slowly break up into a slip on blunging. Time will be saved if it is well ground before or during the mixing with water, but if we wish to break it down as far as possible, so as to loosen the clay from the finest clay-particles, we shall find that nothing is so effective as weathering, that is, exposing the material to the air, rain and drying, heat and frost. The effect of this, when carried over a period ranging from a few days to many months (depending on the particular material) is complex. Oxidation of pyrites, when present, takes place and the mass as a whole will in any case, swell up, losing its shaley structure, and water will be absorbed. The result is a more or less plastic mass. Oxidation of pyrites and similar materials which give rise to coloured metallic oxides, enables a certain amount of cleaning to be effected by the picking out of stained nodules. The nodules are also often more permanently exposed by weathering. In addition to this, sulphuric acid will be formed (dissolving up various bases) where sulphide minerals were in the original shale, and this, on dilution and oxidation, deposits iron, and copper and aluminium if present may be leached out by the clay through which this dilute acid percolates. No doubt also carbon dioxide from carbonates and organic matter (bacterial action) assist in these same processes. Supposing then, that our material is in a plastic state, weathered if necessary, and we mix it with about six times its weight of water, thoroughly, in a blunger. We shall have a slip at rather less than 22 oz. per pint, in the ordinary way. What happens if this is allowed to stand? It settles down. But not

in the way one would expect. If the coarsest grit, such, say, as can be removed on a 100's lawn, is already taken out, the whole of the material appears to settle *en masse*, leaving perfectly clear water on top. The keenest inspection will show no sign of any grading of fine particles from coarse. At a glance, seeing that no fine particles remain in suspension, we might say that no colloidal particles exist in the clays. If this suspension is watered down still further, however, we shall in most cases eventually get a settling of grit and silt and a more or less considerable cloudiness will remain in the supernatent liquid, after long standing. So it appears that colloidally small particles *are* present, but that they need to be separated from one another and from the grit before becoming apparent. To do this by dilution and agitation to the point of using 50 or more tons of water per ton of clay is neither the cheapest nor the best method of procedure, except perhaps where water is most abundant and pure, and the clay can conveniently be washed out of its natural position. As is well-known, the process is impracticable with any but clays of fairly low plasticity and well opened with grit, on account of the enormous volume of water to be dealt with in relation to the clay treated.

Everything points, in such a slip as has been discussed, to a gelatinous structure, and the way in which contraction of a plastic mass of such clay takes place on drying, without the development of air-spaces (referring to the first part of the contraction only), agains shows a strong resemblance to jellies in general. Again, a clay slip of 1·3 to 1·5 specific gravity will shake in a way strangely reminis cent of the familiar table jelly, if the containing vessel is sharply struck, or a spatula be suddenly shaken in it. This resemblance is found not to be illusionary on further investigation. A slip, such as the one above will generally, on testing, be found to be faintly acid in reaction. If, now, this acidity be destroyed and sufficient of a suitable alkaline reagent be added, the suspension shows quite new properties ; clean, fine, sandy grains, black grains of organic matter and bright scales of mica may be seen working their way down through a dense suspension of the finest clay. If the alkali, known in this case as a deflocculant, for its power of breaking up small aggregated masses or floccules, is doing its work perfectly, the settling of these impurities will go on at a slower and slower rate as the suspended impurities remaining are finer and finer. Finally, if left long enough, the coarser particles of the clay itself may separate in large quantities. It is, as a rule, not a difficult matter to draw a practical line between impurities and clay, the main difficulty is to get perfect deflocculation. In practice, a density of slip of 1·25 to 1·3 (25 to 26 oz. per pint) is found suitable, and at this concentration, where the deflocculation is interfered with by other factors, the slip will slowly gelatinise. The falling grains of silt, etc., will gradually slow up and finally stop, bound in an invisible net-work of clay particles. How exactly these clay grains join up we do not know,

but it is probably due to a surface-tension effect of the water-atmospheres which exist around neutral clay particles. The effect, however, remains and is demonstrated later. For the present we will return to deflocculation.

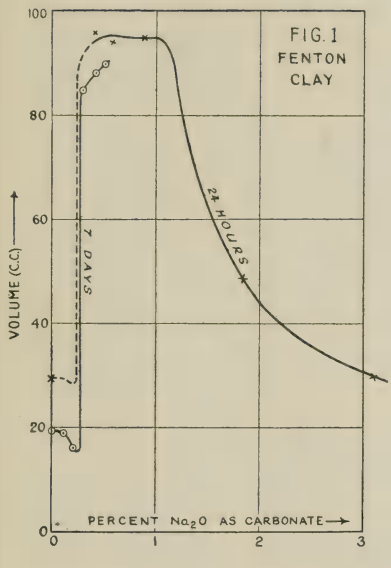
Numerous substances used as deflocculants are found mentioned in patents and other publications. A large group consists of caustic soda and sodium salts of various weak acids ; ammonia is favoured for elutriation of clays ; various organic substances such as tannic acid, humic acid, straw extract, and the waste liquor from the sulphite process for preparing wood-pulp have been used from time to time. Sodium carbonate and sillicate of soda are probably most used and were first studied in connection with this work. Mr. L. S. Theobald examined a considerable selection of other substances for which claims have been made. In no cases, however, did he find a substance more effective than the carbonate or silicate. The examination of the organic substances was left over until such a time as our studies of the simpler cases have cleared up the nature of the effect. It will then be time to tackle cases where new complications are likely to arise.

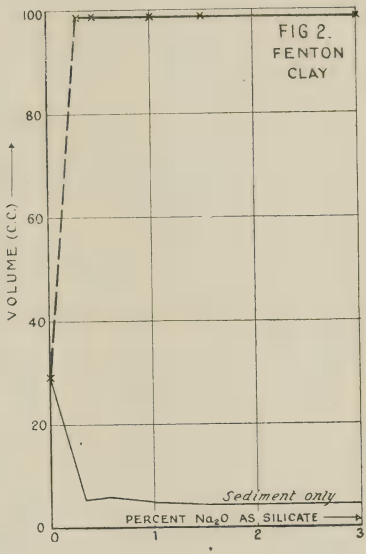
The procedure adopted in the tests is that described by Ashley[1], but modified. Ashley weighed out 5 grms. of dry clay into each of a series of 100 cc. graduated and stoppered cylinders and added successively increasing volumes of a solution of the deflocculation. Each was then made up to 100 cc. with distilled water and shaken for several hours. The state of affairs was noted down after various periods of settling and the best quantity of deflocculant taken as the least at which the clay was fully deflocculated. The writer prefers not to use dry clay, as drying has frequently a considerable effect on the properties of a clay. Also, clays are usually not dried for works purposes, when a slip is to be made of them subsequently, so that such extraneous effects as might be obtained on this account in testing would not appear in large-scale practice. The clay was, therefore, directly blunged up to a slip of 30-31 oz. per pint, at which density fine grit and silt will not settle out and a suitable quantity of this slip taken to give 5 grams of dry solid matter to each tube. Deflocculants were added from a burette at as low initial concentration as possible, and the tubes were not shaken up until made up to full volume. The shaking, owing to the previous blunging, need not last for more than a minute. The cylinders were allowed then to stand 24 hours and again shaken up. Readings were taken after the second period of 24 hours' settling and after 7 days, if further definition of the deflocculation-point was needed. (Readings, when taken after the initial day's settling, were sometimes misleading). The suspensions do not always behave consistently until after this period. Subsequent variations

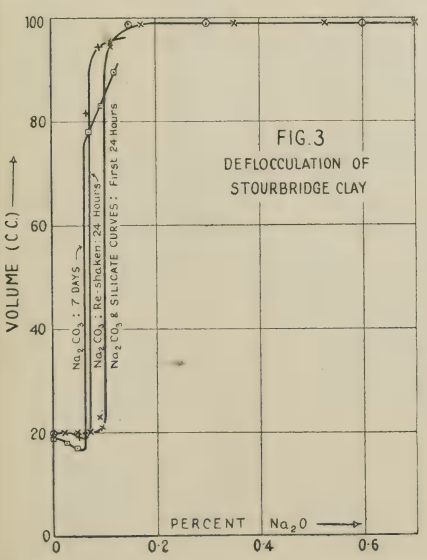
[1] H. E. Ashley, *Trans. Amer. Cer. Soc.* **12**, 768, (1910).

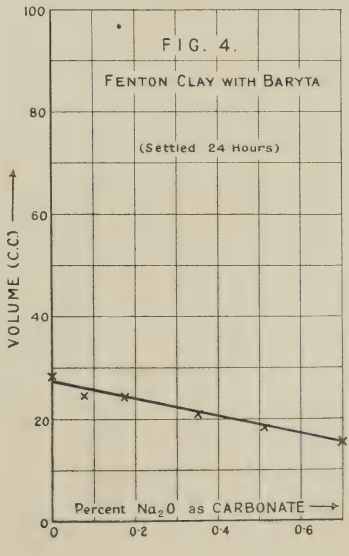
have been found to be too small to affect the conclusions drawn. The cylinders used should be a nearly as possible of one height up to the 100 cc. mark.

In studying the results of such tests it has been found con-









venient to plot graphically the volume of dense suspension *plus* that of sediment against percentage of alkali as base, *i.e.*, Na_2O. The volume of sediment and dense suspension then approximately represents the height in the tubes occupied by the clay, and the greater this height, of course, the greater the degree of deflocculation. Figs. 1, 2, and 3, show the results obtained with sodium carbonate and silicate of soda in conjunction with a Fenton saggar-clay and Stourbridge fireclay. Some of the work was repeated on fresh samples and similar results obtained. Fig. 4 shows the effect of sodium carbonate on the Fenton clay blunged with 0·5 per cent. of barium hydroxide on the weight of clay. The silicate of soda used gave 9·42 per cent. Na_2O at 80° Tw. and therefore, corresponds to about Na_2O. 3·1 SiO_2. These tests were carried out in collaboration with Miss D. A. Jones.

In this connection the work of Comber[2], from the soil chemist's point of view, should be mentioned. He adduces evidence in favour of clays holding considerable quantities of water bound up in such a form that they reduce permeability and do not take part in the solution of substances dissolved in surrounding "free" fluid water. Viscosity studies by the present writer some years ago led him to the same conclusion, to the effect that clays normally hold a relatively large volume of water in a condition in which it does not take part in ordinary fluid motion of the clay slip. Also this "fixed" water was rapidly reduced on deflocculation. There can be little doubt that this "fixed" water has a great bearing on plasticity, which is also reduced by the same treatment. It is hoped to publish this work at a later date, when experiments have been carried out which are considered necessary to a proper understanding of the more gelatinous slips. Comber (*loc. cit.*) further studied the nature of the effect of lime on clays, and noted that the coagulum produced occupied a less volume in the presence of ammonia. This is a very similar case to that of Fig. 4, where the coagulum of clay with baryta is reduced in volume by sodium carbonate, which, like ammonia, normally deflocculates. Thus we see that mere alkalinity (or hydroxyl-ion concentration) is not going to account for all the features of the case. Recent experiments have indicated that hydrochloric acid extracted from clay something which previously interfered with deflocculation. This gives some insight into the mechanism of the process. So it appears that the behaviour of clays can be accounted for on colloidal principles, but taking into account a selective chemical power possessed by the clay grains. This theory will be developed as briefly as possible. Clay consists of particles ranging upwards from colloidal dimensions. These particles are, in general, vastly larger than the simple molecule, $Al_2O_3.2SiO_2.2H_2O$. The clay acts as a very weak acid, and, as its molecule only presents certain portions where combination

[2] Comber, *Journ. Soc. Chem. Ind.*, **41**, 77 (T), (1922).

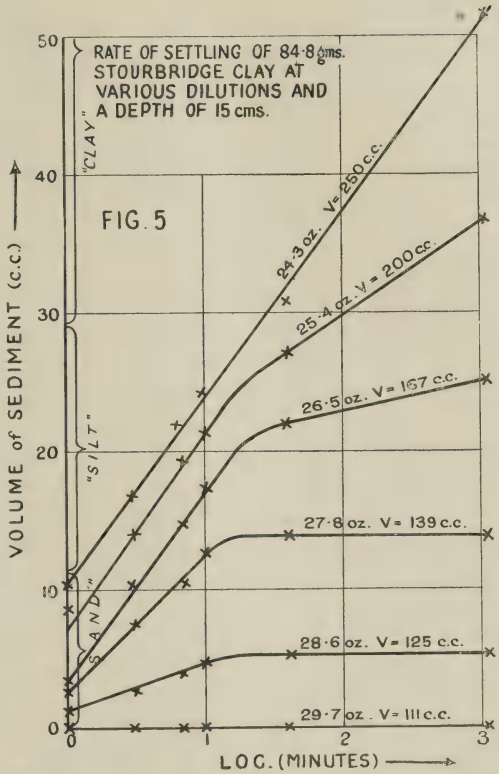
with bases can take place, the larger primary masses in which it exists as clay bury many of these points of attack. In short, the clay grains are only able to take part in chemical reactions at their surface, and the clay acts as a highly polymerised molecule of colloidal or greater dimensions. The surface of this clay grain is then capable of forming compounds with bases, if they are not indeed already formed to some extent throughout the grains. The compounds formed may or may not have a *tendency* to solubility, insolubility or hydrolysis.

Where the base is an alkali metal or ammonium the tendency is to solution, and partial hydrolysis. The result of this is to form ions of the metal or basic group and leave a negative electrical charge on the clay grain. This charge causes mutual repulsion between the clay grains, and loose masses or floccules rapidly break down to a free suspension of the ultimate clay grains. Each grain, however, probably retains its base-ion more or less loosely held, at a distance from it and what is known as a Helmholtz double electric layer is formed. This is consistent with the way in which clay slips and wet clay masses behave when placed between two opposite electric poles. In slips (*i.e.*, suspensions), the clay particles move towards the anode, behaving as though negatively charged. Similarly, where the clay mass is too compact readily to move further, it has been observed that water collects round the cathode, the electrical energy employed working in a comparable manner to the mechanical energy used in filter-pressing. These facts are applied to practical ends in the Osmosis Process for treating clay slips. To return then to our consideration of the state of the clay particles after deflocculation: A certain proportion of the clay-base compound hydrolyses and this results in free metal ions, hydroxyl ions, and clay granules whose surfaces consist of undissociated (as the clay acid is very weak) clay-acid molecules, The surface of the clay grain will now only exhibit the electrical charge peculiar to all surfaces existing between water and pure clay. This is probably extremely minute, in conformity with the almost negligible true solubility of clay in water. Consequently, we may take it that such particles are neutral and tend to coagulate on account of the high surface tension of the water surrounding them. The free alkali, however, in solution will tend to oppose this coagulation, and stability will ordinarily result.

But now if we treat our deflocculated clay with a salt of a base which forms compounds having a tendency to insolubility, such presumably as those of calcium, ferric iron, aluminium, barium, a substance is formed which has practically no tendency to ionisation. The electrical charge on the clay grain is neutralised, the surface tension of the surrounding water rises and there is nothing to oppose the tendency of particles, which come in contact with one another, to become attached. Therefore, coagulation goes on

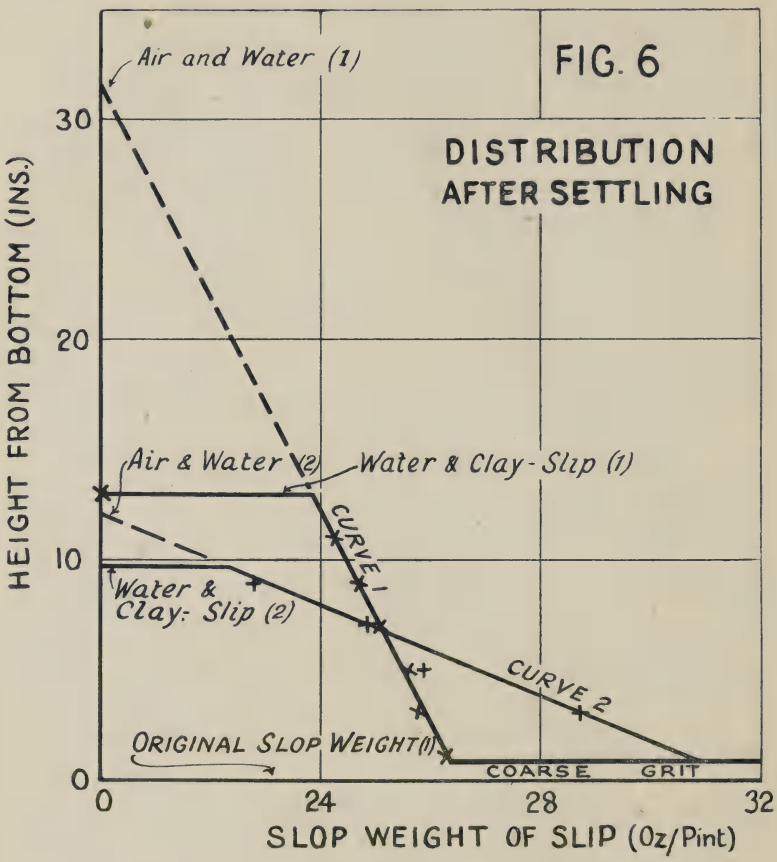
under the influence of a force which is greater the smaller the particles involved. And if, as in this case, the substance is so utterly insoluble that large particles cannot grow rapidly even at the expense of small particles in direct contact with them, the process may extend, in time, throughout the whole suspension and result in a mass which possesses certain of the properties of a solid—a jelly, in other words. A very slight force will, however, be sufficient temporarily to destroy the completeness of this structure, and, consequently, it may be made to flow, but on standing again, it will, more or less, rapidly resume its former solid properties. It is then not difficult to picture the state of affairs existing in a plastic mass of clay, and why it is that there is an unbroken sequence of states between solid clay, through plastic masses, to more and more liquid masses, until finally the average distance between the clay grains is so large that even the most open structure cannot be formed to encompass the whole of the water in a stationary mass. When this happens, settling out occurs, the imperfect network of clay grains carrying all solid particles down with it, until a concentration is at last achieved at which a complete jelly-structure is possible. After this point the weight of the upper part of the jelly, and possibly of the water above it, is sufficient to compress the mass further, the concentration being greatest in the lowest layers, until finally, the weight of the mass may be balanced by the strength of the jelly. On account of the high proportion of water occurring under these conditions, it would appear to be possible to account for the state of affairs by the assumption that the clay grains, like the soap micelles of McBain, unite into weak strings or fibrils and that the jelly consists of a mass of these, interwoven in all directions.

In this connection Figs. 5 and 6 are of interest. The Stourbridge clay in Fig. 5 was being used to prepare a specimen of "Osmosis" clay, and the thin slip from the machine was used for blunging up further clay. The alkali used for deflocculation was sodium carbonate, as certain effects produced by silicate of soda were desired to be avoided. It is estimated that there was 0·23 per cent. Na_2O as carbonate on the weight of the clay. Also, as calcium sulphate was strongly suspected from previous work, and this was conducive to lower yields in the process, 0·11 per cent. of barium carbonate (precipitated) had also been added, with beneficial results. Nevertheless, the best deflocculation that could be attained under these circumstances, was not complete and Fig. 5 illustrates how, at various concentrations of clay in water, the gelatinous nature of the slip gradually asserted itself. Fig. 5 is based on settling tests in which the high density slip was diluted with increasing volumes of water, and settled at nearly 15 cm. depth. Time of settling (in minutes), is taken logarithmically for convenience, and the figures are calculated so as to show the volume of sediment obtained from 84·8 grms. of Stourbridge



fireclay settling in various quantities of water at 15·0 cm. depth, corrected. It is interesting to note that at 29·7 oz. per pint no settlement takes place. Hence down to 26·5 oz. the settling is, sooner or later, arrested by gelatinisation. At 25·4 oz. the gel is too weak entirely to prevent settling, but has a marked retarding effect, and even this disappears at 24·3 oz. A similar series of effects would be obtained at lower slop weights, with less deflocculant present. The use of gentle agitation, as in the Dorr Thickener, would defer the gelatinisation further.

In Fig. 6, with the Fenton saggar-clay, a slip of 23·3 oz. per pint was settled for 95½ hours, the depth being 31 ins. No deflocculant was present in this case, so that the slip settled with a sharp surface between the clay and the over-lying clear water. The state of affairs at the end of this period is shown in Curve 1. The clear water was later drawn off to a remaining depth of 12 ins. After a total settling-time of 145 hours the state of affairs was as shown in Curve 2. It appears more than a coincidence that the amount of solids at any depth below the clay level is directly



proportional to the depth. As far as the writer can see, the only rational explanation of this is that the "fixed" water (which is probably the greater part of the water present in the case of a continuous coagulum of this kind) is so bound up by the clay-grains that these form a semi-permeable membrane around it. Consequently, the complex gets squeezed drier by hydrostatic pressure the deeper it lies. It of course remains to be proved to what degree of perfection the gelatinised clay acts as a semi-permeable membrane. Otherwise, if we are not to assume the secretion of "fixed" water in this way, the distribution of solids in the coagulated slip after long standing should depend only on the depth below the surface of the coagulum. This is clearly not so from Fig. 6. It seems very probable then, that in the case of Fig. 4 the gelatinous slip is a barium-clay compound holding a large proportion of "fixed" water; and that the addition of sodium car-

bonate causes this to contract and settle more rapidly on account of the osmotic pressure-effect of the salt (carbonate) dissolved in the water surrounding the aggregates of clay grains. The shrinkage is, at any rate, approximately proportional to the percentage of sodium carbonate.

On this basis, then, a fuller understanding of Figs. 1, 2, and 3 is possible. Taking Fig. 1, in the first place dissolved salts from the clay and the water used (tap water of about 15 degrees of hardness, in this case) and bases such as ferric hydroxide present in the clay cause the clay to be in a coagulated condition. As more and more alkali is added, more and more of these bases are replaced by soda ; but, for a time, the structure is predominantly gelatinous and settles down to a clear liquid, straining off all smaller particles in its path. As fixed water is liberated in this process, the coagulum shows a reduced volume. But a point comes when the remaining gelatinous particles can no longer form up. At this point the suspension appears to have been suddenly deflocculated. It would seem that the phenomena could be explicable quantitatively by the theory of reversible reactions. An important feature of the case is what becomes of the dispossessed bases. These are free to combine with the acidic radicle brought in by the alkali. Now, if a substance of very low solubility, such as calcium carbonate or silicate is formed, this tends to help deflocculation, whereas if caustic soda or sodium sulphate were used, the calcium would remain fairly active in solution and oppose deflocculation.

The change back to coagulation at the higher concentration of alkali is probably a comparable case to the salting out of soap and the numerous cases in analytical chemistry where the addition of a common ion reduces ionisation and solubility. It is interesting to note in Fig. 1 that the effect of 3 per cent. of alkali is to bring the coagulated clay back to the same volume as with none at all.

Fig. 2 resembles Fig. 1 as far as can be judged, for the earlier part of the curve, but is remarkable in that no re-coagulation occurs at the higher concentrations. Clays deflocculated with silicate of soda and separated electrically ("Osmosis" process), so that the majority of the alkali added is separated from the clay, show increased porosity and reduced strength when dried. These effects are proportional to the amount of silicate of soda originally used. Bearing in mind that silicate of soda solutions largely consist of colloidal hydrated silica (complex silicic acids), deflocculated by alkali, there can be no doubt, at least in the author's mind, that the silicic acid is deposited as a gel on the clay grains when these have been deflocculated by the alkali. The result of this covering up of the grains is that they no longer exhibit the properties of clay, but only of the enveloping silicic acid, and as this is stable over a very wide range of concentration, the peculiar behaviour is accounted for,

"Osmosis" clay, which had been prepared with silicate of soda, was tested in a deflocculation-series with sodium carbonate, and it

was found to remain deflocculated after 24 hours with all concentrations of Na_2O from zero up to 3·0 per cent. A very peculiar slime, however, settles out in time. This possessed the property of being so solid apparently that it could only be dug out of a deposit by some force, giving a lump in the hand of what was apparently sticky clay. This, however, very soon commenced to flow and would eventually almost entirely flow away in the course of a few minutes. The hole from which it was dug also completely disappeared after a time.

The Stourbridge clay results in Fig. 3 need no further discussion. It is notable that with both clays and reagents, deflocculation depended on the percentage of alkali, *i.e.*, the same amount of soda was required, whether as carbonate or silicate, to bring about deflocculation.

Finally it should be stated that, from the writer's observations, deflocculation and coagulation phenomena are not restricted to particles of collodial size, but are evident in a less degree with much larger particles. In fact, the theoretical ideas developed would appear to hold for all sizes, the intensity of the effects observed being governed by the surface factor of the material. For example, ground flint suspensions can be partly deflocculated by hydrochloric acid and coagulated by ammonia. There is need for further research in this field. Some results of tests on clays prepared in various ways for a previous report on the "Osmosis" Process are appended. Others will be published later.

Analysis and Tests on Normal Products.

The writer is indebted to Miss D. A. Jones, B.Sc. for assistance in carrying out this and the following sections.

The following tables summarise the results:

Ultimate Analyses.

ANALYSIS OF RAW AND PREPARED SAMPLES

	1		(O) 2	(P) 2	(P) 4	(O) 5	Average of 3 & 4		Average of 2 & 5	
SiO_2	49·0		53·4	55·4	58·3	53·7	56·9		53·6	
TiO_2	1·0		1·4	1·4	1·3	1·3	1·3		1·4	
Al_2O_3	25·8		30·8	27·4	27·1	31·5	27·3		31·3	
Fe_2O_3	8·8		1·8	2·5	1·7	1·6	2·1		1·7	
MgO	0·9	1·5	0·4	1·1	0·6	0·6	0·9	1·9	0·3	1·4
CaO	0·6		0·8	1·1	0·8	1·0	1·0		0·9	
K_2O	1·9	2·1	1·9	1·8	1·2	1·8	1·5	2·2	1·9	2·3
Na_2O	0·2		0·4	1·0	0·4	0·3	0·7		0·4	
Loss above 109°C	11·6		8·5	8·9	8·2	8·7	8·6		8·6	
TOTALS	99·8		99·4	100·4	99·6	100·5	100·3		100·1	

Rational Analyses.

	1 %	2 %	3 %	4 %	5 %	Average of 3 & 4 %	Average of 2 & 5 %
Clay substance	61·5	70·8	61·5	63·5	71·8	62·5	71·3
Felspathic (or micaceous) matters	13·3	13·8	17·2	9·7	12·7	13·4	13·2
Quartz ..	15·3	13·3	17·7	24·0	13·0	20·9	13·1
Iron Oxide ..	9·2	1·7	2·5	1·7	1·6	2·1	1·7
Lime ..	0·5	0·7	1·1	0·8	1·0	1·0	0·9
TOTALS ..	99·8	100·3	100·0	99·7	100·1	99·9	100·2

1. Raw, weathered clay. About 4 kilos were blunged to a slip of about 28 oz. per pint, put through a 40's lawn to retain the very coarsest grit (of which there was only a trace) and also any unblunged clay, and dried down on a plaster slab until stiff enough for ordinary plastic working. The clay was then wedged and a sample cut from the middle and dried for analysis. The analysis related to a sample of the first batch of clay.

2. Clay deflocculated with 0·5 per cent. Na_2O, of which 0·25 per cent. was in the form of sodium carbonate and 0·25 per cent. as silicate of soda, 70°Tw., and put through the Osmosis machine. The analysis is of the product delivered off the drum.

3. The slip which passed off from the Osmosis machine in preparing (2) was coagulated with hydrochloric acid and filter-pressed, and the residual clay tested.

4. Clay deflocculated with 0·20 per cent. Na_2O as silicate of soda, settled thoroughly, treated with sulphuric acid equivalent to 0·20 per cent. Na_2O, and filter-pressed.

5. Deflocculated as in (4). Osmosed on the larger machine. The sample was taken from a batch of several hundredweights of material purified under similar conditions.

The following table, condensed from the above, brings out some of the general relations :—

Treatment of clay	Contraction		Loss in weight	Refractoriness
	Wet to Dry	Dry to Fired at Cone 01A		
	%	%	%	Seger Cone
Untreated ..	5·94	5·72	11·40	18·5
Osmosed ..	7·14	6·68	8·85	29·9
Residual clay after Osmosing	7·20	7·18	8·85	30·5

REFRACTORINESS, ETC. OF RAW AND PREPARED SAMPLES.
(Fenton Clay).

Prep.	Deflocculant per cent. on dry wt.	Put through lawn	Other treatment	Contraction		Loss in weight		Volume porosity dry	Refract-oriness	Remarks
				Wet to dry	Dry to fired at cone 01A	Wet to dry	Dry to fired at Cone 01A			
		meshes per in.		%	%	%	%	%	Seger cone	
A	Nil	40	Nil	5·94	5·72	19·48	11·40	—	18–19	Lowest refractoriness
B	·012% Na_2O as carbonate. Incomplete de-flocculation	40	Settled roughly and Osmosed	5·5	6·10	—	—	25·4	30	
C	·48% Na_2O as carbonate	40	Settled roughly and Osmosed	7·88	6·42	21·60	9·24	29·8	28–29	Greatest wet to dry contraction
D	·48% Na_2O as carbonate	40	Settled 1½ hrs. and Osmosed	7·10	5·60	22·30	8·78	30·0	30–31	
E	·50% Na_2O as silicate	60	Settled and Osmosed	7·47	7·90	28·23	8·65	35·7	30	Greatest loss on drying. Greatest porosity
F	Mixture of slip residue of D & E	—	Osmosed again (no sediment before or after)	7·73	7·37	25·15	8·72	32·8	30–31	Good firm de-deposit on machine
G	Coagulated residues from F. by slight excess of HCl	—	Filter-pressed	7·20	7·18	24·82	8·85	33·4	30–31	

The main conclusions drawn from the facts are as follows :—

(I.) Sedimentation (as a consequence of deflocculation) notably reduces the percentage of iron in the clay, but does not eliminate it entirely. The Osmosis machine effects no further separation of iron.

(II.) Sedimentation either does not affect the proportion of other impurities (titania, alkalies, and alkaline earths) or slightly concentrates them with the clay. The Osmosis machine does not affect the production of these impurities.

(III.) Sedimentation gives a finer-grained product and increases the contraction on drying and on firing and increases the refractoriness of the clay. The osmosis machine produces, practically, no further effect on these properties, where the sedimentation has been carried out thoroughly and with due consideration of the principles involved.

(IV.) Treatment with silicate of soda, by the deposition of gelatinous silicic acid on the clay, causes it to be workable with a higher proportion of water, and the clay when subsequently dried shows a higher porosity.

(V). According to the rational analyses the proportion of clay substance to quartz is lower than in the original material for the settled and pressed clay and higher for the Osmosed clay. (The amount of faith to be put in rational analyses is left to the reader).

3. METHODS OF LARGE-SCALE OPERATION.

The various sedimentation processes for purifying clay may be dealt with in summarised form as follows :—A-B-C-D-E-F represents the series of operations, certain of which may be omitted, according to circumstances. Alternative treatments are indicated under each heading.

A. Weathering. For hard shaley materials.

B. Slip-Making.

(1) China Clay : Washing out, in place of mining or quarrying. Involves use of about 50 tons water per ton clay.

(2) China Clay : Material fed continuously to a washer to which alkali or returned alkaline slip may be added. Requires about 2 tons water per ton clay. Coarse grit is removed by a sand-wheel or similar device.

(3) Plastic clays, etc. : Blunging. Requires about 2 tons water per ton of clay.

C. Deflocculation, by addition of Na_2CO_3 or silicate of soda, NaOH, etc.

(1) In the blunger, in case of B (2) and in B (3) if desired. Further water will probably be needed.

(2) In a second blunger following B (3). Water added.

(3) Added to a stream of slip from B (3) or storage tanks, followed by passing the slip over cataracts or similar devices for mixing. Extra water may be needed at this stage.

D. *Settling-out of Impurities.* (Some grit may settle out directly after B (3).

(1) The slip is cascaded into a deep, rather narrow tank in which fine sand settles out.

(2) A very slow flow of slip is maintained in a long shallow trough. This is used for removing mica or the coarsest part of china clay. Sproat[3] used this continuous (or, as he called it, "Flotation") process for removing impurities from Georgia kaolin. He attached importance to widening this trough into a perfectly level fan-shape, 25 ft. long, 2 ft. wide at inlet and 7 ft. at outlet.

(3) Batch settling in tanks. Not favoured for big outputs; will not be as effective as settling continuously (moving slip) unless deflocculation is complete.

(4) Lawns, stationary or rotating, to remove floating debris. This is usually combined with one or more of the other processes in this section. (1)—(2)—(4) may be employed in treating china clay (see "Osmosis" report).

E. *Separation of Clay.*

(1) Coagulation with sulphuric acid, alum or aluminium sulphate (etc.) by adding the solution to the slip and passing over cataracts or riffles. This is followed by settling in large tanks. The slip concentrated at the bottom is pumped off to filter-presses. "Osmosis" filter-presses may be used. Sproat (*loc. cit.*) maintains that, if sulphuric acid equivalent to the caustic soda used for deflocculation is employed, the water from the presses may be used over and over again. One would, however, expect trouble in time from the accumulation of sodium sulphate in the water, It would be interesting to know whether this has since been encountered.

(2) With china clays, when no deflocculant has been used, as in B (1), settling may take place satisfactorily without the use of a coagulant. The concentrated slip may be filter-pressed, or dried out on a slip-kiln, as is usual with English china clays.

(3) Separation by the "Osmosis" machine following D (4), returning a large proportion of clay in the slip for re-use in the washers, B (2).

(4) "Osmosis" filter-pressing of the slip D (4).

F. *Final Treatment.*

(1) The clay from the "Osmosis" machines or filter-presses may be pugged, extruded through a die, and cut up into slabs of special form, and dried on racks.

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[3] Sproat, *Jour. Amer Cer. Soc.*, **18**, 767, 1916.

(2) As in F (1), but drying in a tunnel-dryer heated by steam or in a rotating-drum dryer heated by producer-gas, as used for china clay from D (2).

(3) Concentrated slip may be used direct from E (1), for bonding non-plastic materials.

(4) Drying on a slip-kiln, as under E (2) for china clay.

The process under E (1) may be made continuous by settling in a suitable large tank provided with overflow for clarified water. This tank should have a sloping bottom in the form of an inverted pyramid or cone, at the base of which, concentrated slip is drawn off continuously to feed-tanks for filter-presses. If preliminary treatment with acid, as mentioned on p. 240, is necessary to ensure good deflocculation and additional purity of product, this will take place between blunging B (3) and deflocculation. It will involve the use of additional large settling tanks, as for E (1), and a large volume of water. Silicate of soda involves difficulties in coagulation, and is perhaps best avoided except where the "Osmosis" machine or "Osmosis" filter-press is used. The effect on the purified clay should, of course, be borne in mind.

The selection of a process from the alternatives given in the above summary depends upon many factors, the principal of which are :—

(*a*) Nature of clay to be treated.

(*b*) Availability or otherwise of large supplies of pure water.

(*c*) Cost of electricity, if "Osmosis" processes are used.

(*d*) Nature of proposed site. If sloping land is available with a water supply above, pumping may very largely be eliminated. As an off-set to this is the desirability of covering over a large part of the plant if regular continuous working is desired.

In any case, except, possibly, that of the simple process generally adopted in the English China Clay trade, it is courting disaster not to employ the services of a suitably-trained technical chemist. As mentioned in the early part of this report, this research has not yet been completed, so that no particulars (apart from the previous report referred to) have been studied in detail as regards cost. It would appear, however, that the treatment (apart from drying), by settling and filter-pressing under favourable conditions, would cost about 13s. 0d. per ton for an output of 100 tons per week, and a capital expenditure of the order of £10,000, 5 per cent. interest on this amount being allowed in the above cost. This figure cannot be taken as applying to *any* clay, but rather to the general run of plastic clays which do not present unusual difficulties in treatment.

In conclusion, I have appended a few notes on settling. W. A. Deane[4] of the Dorr Thickener Company, gives a very clear discussion of the general problem of settling. He gives formulæ from which the dimensions of settling tanks for various purposes can readily be calculated. He advocates the use of the Dorr Thickener for general settling purposes. This, however, would not apparently be quite suitable with clays on account of the low rate of settling encountered, and the fact that after free settling is completed with clays the concentrated slip is still quite capable of flowing evenly without mechanical aid. The same considerations can, however, be applied to simple settling tanks working continuously as suggested on p. 251. The Dorr Thickener is worthy of special attention as a means of removing comparatively coarse, rapid-settling impurities. A series of settling tests on the Fenton clay, a gritty mixture of clays, and a china clay, showed that the rate of free settling (cm. per hour) is approximately inversely proportional to the concentration of solids in the original slip (gm. per cc.) and that there is no great difference in this respect between the three types studied. The product of rate of free settling and concentration is round about 0·45 in all cases where the slip is thoroughly coagulated. It would appear to be quite possible to settle such slips in a tank drawing off slip at 24 to 25 oz. per pint (specific gravity 1·2 to 1·25) from the bottom for the filter-presses. No difficulty was encountered in obtaining a good hard filter-cake from well coagulated slips. Deflocculated slips, on the other hand, were practically impossible to press up to a solid cake. It is not considered necessary to give the settling curves obtained. They generally consist of a portion indicating free settling followed by much slower settling as the gelatinous mass finally compacts itself. In certain cases the curves were not so simple, by the final practical result, for our purposes, was the same.

[4] W. A. Deane, "Settling" problems, *Trans. Amer. Electro-Chem. Soc.*, **37**, 71, (1920).

XX.—The Influence of Texture on the Transmission of Heat through Firebricks.*

A. T. Green.

[Communication from the Clay and Pottery Laboratory, Stoke-on-Trent, No. 110].

Introduction.

THE transmission of heat through firebricks takes place by way of both the solid matter and the pores. It has been stated that the transference of heat through the pores is very small compared with that transmitted through the solid matter, or in other words, pore-spaces consistently maintain insulating properties. It would thus follow that the higher the porosity of a refractory material, the greater ought its insulating effect to be. This argument appears to be justified by the fact that such highly porous materials as diatomaceous earth bricks possess pronounced insulating properties at lower temperatures[1] (*i.e.*, up to, at least, 700°C.), and thus under the accepted conditions of their use. However, some investigators, notably Mellor[2], have, as the result of practical observations and of theoretical deductions, suggested the hypothesis that at high temperatures, heat may be transmitted by way of the pores, at a rate which is comparable with that of conduction through the solid matter. In an earlier work[3] by the present author, two facts seemed to bear out this hypothesis. In the first place the pronounced rate of increase in the value of the coefficient of thermal conductivity of some bricks with temperature, at temperatures above 1,000°C., was suggestive of influences additional to the conduction of heat through the solid matter. Again, a calculation based on the fourth power radiation law, and the data obtained from the determinations of thermal conductivity showed that the rate of heat transmission by radiation across the pore-spaces may be, at temperatures over 1,100°C., at least, comparable with the rate of heat conduction through the solid matter.

In the paper mentioned above, it was pointed out that the essential factors governing the effect of the pore spaces appeared to be (1) the temperature; (2) the size of the pores; (3) their disposition with respect to the solid matter. In other words, it can be stated that previous work has suggested the view that the rate of heat transmission, through certain refractory materials is dependent, in some degree, on the temperature and texture of the material, in a manner contrary to a general expectation. The present work was commenced with the object of testing this suggestion.

Materials of Experiment.

The Making. The difficulty of obtaining firebricks identical in composition and constitution (*i.e.*, of identical "material factor"),

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and yet possessing different textures is very great. This fact will be noted in the study of the properties of the different classes of bricks used in this investigation. However, with the object of confining this "material-factor" to a narrow range of variation, all the bricks were made from one batch of Stourbridge fireclay. The grog used was made from the same clay, at a particular firing. This grog was divided into three grades, *i.e.*, (1) that which passed through a $\frac{1}{16}$'s lawn; (2) that which passed through an $\frac{1}{8}$'s lawn and stayed on an $\frac{1}{16}$'s lawn; that which passed through $\frac{1}{4}$'s lawn and stayed on an $\frac{1}{8}$'s lawn. The bricks were made up of the following mixtures:

TABLE I.

BATCH I.

Grog passes through $\frac{1}{16}$'s lawn.

Mark	*A*	*B*	*C*	*D*	*E*	F
Clay (parts by weight) ..	10	9	8	7	6	5
Grog (parts by weight ..	0	1	2	3	4	5

BATCH II.

Grog passed through $\frac{1}{8}$'s lawn and stayed on $\frac{1}{16}$'s lawn.

Mark	*G*	*H*	*I*	*J*	*K*	
Clay (parts by weight) ..	9	8	7	6	5	
Grog (parts by weight) ..	1	2	3	4	5	

BATCH III.

Grog passed through $\frac{1}{4}$'s lawn and stayed on $\frac{1}{8}$'s lawn.

Mark	*L*	*M*	*N*	*O*	*P*	
Clay (parts by weight) ..	9	8	7	6	5	
Grog (parts by weight) ..	1	2	3	4	5	

Each of the above mixtures was assembled and prepared by hand, and after allowing to stand for a short time, was slop moulded. Twelve bricks of each mark were made. They were then fired to Cone 10. The analysis of a fired brick *F* showed SiO_2, 69·94%; Al_2O_3, 23·50; Fe_2O_3, 1·75%; TiO_2, 1·27%.

The Properties. The investigated properties of all the bricks are appended in Table II.

TABLE II.

Mark	% Apparent Porosity (*A*)	% True Porosity (*B*)	Diff. between *B* & *A*.	True Sp. G.	App. Sp. Gr.	Crushing Strength in lbs./sq. inch
			Batch	No. 1.		
A	22·04	25·65	3·61	2·631	1·956	5080
B	22·75	25·92	3·17	2·627	1·946	5434
C	26·91	27·72	0·81	2·626	1·898	4244
D	27·21	27·92	0·71	2·622	1·890	4055
E	27·91	28·19	0·28	2·618	1·880	3141
F	28·32	28·52	0·20	2·616	1·870	2325
			Batch	No. 2.		
G	23·21	25·41	2·20	2·617	1·952	3358
H	24·62	25·26	0·64	2·609	1·950	2810
I	24·68	25·70	1·02	2·607	1·937	2155
J	25·32	26·47	1·15	2·604	1·914	2092
K	26·33	27·14	0·81	2·601	1·895	1296
			Batch	No. 3.		
L	24·05	25·54	1·49	2·623	1·952	3822
M	25·20	26·00	0·80	2·615	1·935	2729
N	25·00	26·00	1·00	2·610	1·931	1646
O	25·75	26·40	0·65	2·610	1·921	1264
P	25·91	26·88	0·91	2·612	1·910	1132

The instructions to the manufacturer stated that the burning should be identical for all batches. However, some variation in this burning appears to have occurred since the average true specific gravity of Batch I. is 2·622, of Batch II. 2·607, and of Batch III. 2·614. The specific gravity determinations, on which the figures are based, were obtained by the use of specific gravity bottles. Special precautions, including (1) the use of paraffin as the liquid; (2) the use of a vacuum pump and (3) the use of a thermostat, were taken, and, as a result of these an error of not more than 0·005 for each determination is anticipated. Two determinations were made for each brick and the average taken. It is considered probable that a difference of two cones in the "firing" will cause the variation from 2·622 to 2·607 noted in the average specific gravity.[4] The decrease in the true specific gravity with increasing grog content is a feature of each batch. This fact points to the opinion that an increase in the amount of heat work to which the bricks are subjected, in the region of Cone 10, results in a decrease in the specific gravity of the material This is well illustrated in Fig. 1. Thus it appears that Batch II. has received more "fire" than Batch III. which, in turn, has received more "fire" than Batch I.

Apparent porosities were determined by the usual method, from the data (1) weight of a piece of dry brick; (2) weight when soaked in paraffin; (3) weight of this piece when suspended in

paraffin. The average of four of the most concordant of six determinations was taken. The determinations do not show a wide range of porosity although actually other factors must be considered. With each of the bricks *A*, *B*, *G* and *L* the presence of large holes interspersed throughout the semi-vitrified mass, was very marked. In fact, the porosity determinations on this account were very variable. These holes were noticed in at least half the pieces of bricks used for the determinations. This suggests that the apparent porosities reported for the bricks *A*, *B*, *G* and *L* include at least two types (1) large holes due to the nature of the clay, the nature of the making process and the insufficiency of grog of the correct grade (2) the finer pores running through the semi-vitrified mass. Again, in these bricks, another type of pore must be considered. The existence of this kind is suggested by the percentage true porosity. This quantity is computed from (*a*) the apparent specific gravity which is obtained from the same data as the percentage apparent porosity ; and (*b*) the true specific gravity of the material. The result obtained includes, within the limits of experimental error, the whole of the pores of the material. It shows that bricks *A*, *B*, *G*, and *L* contain some pores, to which the paraffin, even under the pressure of a vacuum pump, cannot gain access. These pores are referred to as "sealed pores." Fig. 2 shows graphically the increase in porosity with increasing grog content.

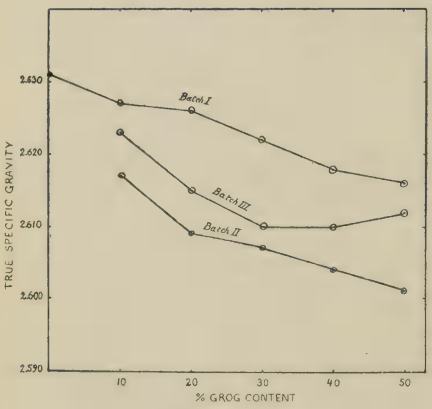


Fig. 1.

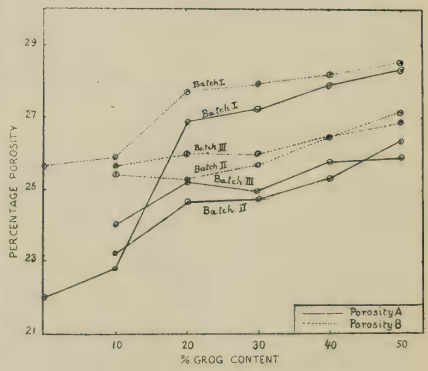


Fig. 2.

The possibility of the motion of hot air within the brick during conductivity determinations was early realized. The property, termed the *permeability* of the material, which is a controlling factor in the passage of the hot gases through the brick, is difficult to measure accurately. Such a property is obviously a function of the texture of the material, and consequently, it was thought that a knowledge of the crushing strength together with the porosity

of the material would give some idea of the permeability of the material under experiment. For this reason the crushing strength determinations are appended in Table I. and graphed in Fig. 3. These results are also interesting since they give a quantitative idea of the effect of increasing amount of grog of the same grain size, together with the effect of grain size itself, on the crushing strength of manufactured bricks.

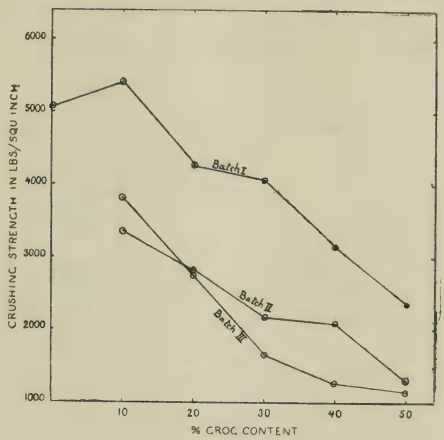


Fig. 3.

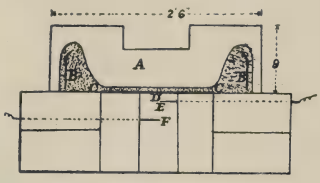
The Determination of the Thermal Conductivity.

The method adopted for the determination of the coefficient of thermal conductivity has been fully described in a previous publication.[3] The following résumé of this description is added in order to make an interpretation of the results more clear. Firstly, the procedure consists in maintaining an even and constant temperature on the hot face of a wall composed of nine bricks of the material under test, from the beginning to the end of the experiment. An electric furnace based on the principle of the Hirsch refractory testing furnace is used for this purpose (see figs. 4 and 5). The second part of the work consists in measuring at fixed intervals of time—usually every hour—the temperatures of two isothermal planes at distances of about 5 cms. and 8 cms. respectively from the hot face. These data are obtained by two thermo-couples, secured in holes $\frac{3}{16}''$ in diameter in a central brick. Such temperatures are referred to as the 1st hole and the 2nd hole temperatures respectively.

This experimental method is based on Fourier's law of linear diffusion. Thus by evaluating $\frac{\theta_0 - \theta}{\theta_0}$ where θ_0 is the constant hot

Fig. 4.

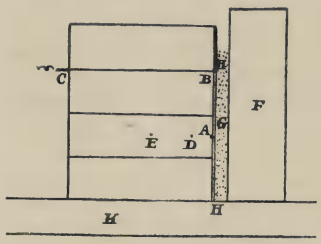
Cross-Section through Plane of Thermo-Couple Holes parallel to the Base of Apparatus.



A, furnace part of refractory clay.
BB, electrodes.
CC, hot plate.
D, face thermo-couple.
E, 1st hole thermo-couple.
F, 2nd hole thermo-couple.

Fig. 5.

Cross-Section perpendicular to the Plane of the Thermo-Couple Holes.



A D E, position of three thermo-couples.
A B C, shows the path of the face thermo-couple.
F, furnace part.
G, graphite resister.
HH, hot plate.
K, base of apparatus.

face temperature and θ the hole temperature after a specific time (about 7·5 hrs.) has elapsed—a factor is obtained which, together with certain mathematical tables, defines a numerical value for the expression $\frac{x}{2\sqrt{kt}}$. Since x is the distance of the hole from the hot face and t is the time which has elapsed from the commencement of the experiment until the temperature θ is obtained at this hole, k, which is the diffusivity or "temperature conductivity" of the material can be readily obtained. The value of k, so obtained is the average value between the temperature limits θ_0 and θ. To calculate the coefficient of thermal conductivity between the temperature limits θ_0 and θ we have the equation.

Thermal conductivity$=k.c.s.$ where k is the determined diffusivity, c is the apparent specific gravity of the material and s is the specific heat of the material between the two temperature limits θ_0 and θ. The product $c.s.$ is thus the heat capacity per unit volume.

Results.

The results of the thermal conductivity experiments are appended in Tables III. and IV.

Table III.
Conductivity Results for Brick A.

1st Hole Determinations.				2nd Hole Determinations.		
Temp. Range	Temp. Range No.	Mean Diffusivity in C.G.S units	Mean Thermal Conductivity in C.G.S. units	Temp. Range	Mean Diffusivity in C.G.S. units	Mean Thermal Conductivity in C.G.S. units
920°–612°C.	(1)	0·00259	0·00155	920°–480°C.	0·00266	0·00153
1037°–697°C.	(2)	0·00265	0·00163	1037°–547°C.	0·00270	0·00161
1153°–786°C.	(3)	0·00275	0·00175	1153°–615°C.	0·00278	0·00171
1270°–870°C.	(4)	0·00282	0·00184	1270°–687°C.	0·00281	0·00179

TABLE IV. Batch No. 1.

		1st Hole Determinations.		2nd Hole Determinations.	
Mark	Temp. Range No.	Mean Diffusivity in C.G.S. Units	Mean Thermal Conductivity in C.G.S. Units	Mean Diffusivity in C.G.S. Units	Mean Thermal Conductivity in C.G.S. Units
B	(1)	—	—	—	—
	(2)	0·00262	0·00161	0·00275	0·00163
	(3)	0·00275	0·00174	0·00282	0·00174
	(4)	0·00280	0·00183	0·00290	0·00183
C	(1)	0·00249	0·00144	0·00253	0·00140
	(2)	0·00259	0·00154	0·00270	0·00155
	(3)	0·00271	0·00167	0·00277	0·00166
	(4)	0·00282	0·00179	0·00294	0·00182
D	(1)	0·00234	0·00134	0·00235	0·00129
	(2)	—	—	—	—
	(3)	0·00260	0·00160	0·00272	0·00161
	(4)	0·00275	0·00174	0·00290	0·00178
E	(1)	0·00240	0·00137	0·00242	0·00133
	(2)	0·00253	0·00149	0·00272	0·00152
	(3)	0·00267	0·00163	0·00286	0·00169
	(4)	0·00286	0·00180	0·00298	0·00184
F	(1)	0·00233	0·00132	0·00235	0·00128
	(2)	0·00256	0·00151	0·00259	0·00148
	(3)	0·00282	0·00171	0·00299	0·00176
	(4)	0·00310	0·00194	0·00307	0·00186

The hot face temperatures used in the majority of the experiments were 920°C. 1,037°C., 1,153°C. and 1,270°C. These temperatures, which may appear a peculiar selection,were occasioned by the fact that the face thermocouple and the galvanometer were not made for each other. Consequently, although easily controllable temperatures were used, the above temperatures resulted from the standardization of this couple and the galvanometer against substances of known melting points and against a standard thermocouple. If the face temperature used was different from those mentioned above, a computation served to bring it to the same basis. For brick *A*, the temperature ranges are given, but, since the variation of the hole temperatures was rarely more than 25°C. from an average for the particular range,it was considered that the categories, temperature ranges Nos. (1), (2), (3) and (4), would suffice to indicate the respective ranges without introducing any appreciable error. The time factor averaged about 7·4 hrs., while the distance factor varied from 4·7—5·4 cms. in the case of the first hole, and from 7·7—8·3 cms. in the case of the second hole.

Since the temperature of the second hole is lower than that of the first, the results computed from the experimental data of the second hole should be correspondingly lower. As a matter of experiment, the

Table IV.—*Continued.* Batch No. 2.

		1st Hole Determinations.		2nd Hole Determinations.	
Mark	Temp. Range No.	Mean Diffusivity in C.G.S. Units	Mean Thermal Conductivity in C.G.S. Units	Mean Diffusivity in C.G.S. Units	Mean Thermal Conductivity in C.G.S. Units
G	(1)	0·00268	0·00159	0·00268	0·00153
	(2)	0·00284	0·00174	0·00280	0·00167
	(3)	0·00299	0·00190	0·00298	0·00183
	(4)	0·00310	0·00203	0·00308	0·00195
H	(1)	0·00268	0·00159	0·00272	0·00155
	(2)	0·00280	0·00172	0·00286	0·00170
	(3)	0·00294	0·00186	0·00296	0·00181
	(4)	0·00308	0·00201	0·00308	0·00194
I	(1)	—	—	—	—
	(2)	0·00269	0·00163	0·00261	0·00154
	(3)	0·00282	0·00173	0·00276	0·00165
	(4)	0·00305	0·00195	0·00298	0·00185
J	(1)	0·00252	0·00147	0·00260	0·00146
	(2)	0·00266	0·00162	0·00270	0·00158
	(3)	0·00289	0·00180	0·00284	0·00171
	(4)	0·00306	0·00196	0·00308	0·00192
K	(1)	0·00246	0·00142	0·00268	0·00149
	(2)	0·00259	0·00155	0·00270	0·00156
	(3)	0·00280	0·00171	0·00295	0·00176
	(4)	0·00300	0·00190	0·00310	0·00191

diffusivity results are inclined to be higher, a fact noted in previous work on the subject of the thermal conductivity of refractories. The argument that the first hole somewhat disturbs the flow of heat, with a consequent effect on the second hole temperature, has already been put forward. The function of the second hole result, however, is merely to check that obtained fron the first hole.

Discussion of Results.

Comparison of Batches. A general consideration of the results of the three batches points definitely to the fact that Batch II. possesses the highest average conductivity. Batch III. comes next, with Batch I. possessing the lowest average value of this "constant." It has been previously noted that the average specific gravities follow the reverse order with Batch No. II. possessing the least value. This was taken as an indication that Batch No. II. had received the most "fire," and Batch No. I. the least. It is thus suggested that the greater the amount of "fire" which the firebrick has received, the higher will be the value of its coefficient of thermal conductivity. Similar facts have been previously brought forward by Wologdine[5], and others. Fig. 6 shows graphically the relation between average specific gravity and the average

Batch No. 3.

		1st Hole Determinations.		2nd Hole Determinations.	
Mark	Temp. Range No.	Mean Diffusivity in C.G.S. Units	Mean Thermal Conductivity in C.G.S. Units	Mean Diffusivity in C.G.S. Units	Mean Thermal Conductivity in C.G.S. Units
L	(1)	0·00259	0·00154	0·00272	0·00156
	(2)	0·00267	0·00164	0·00280	0·00167
	(3)	0·00282	0·00179	0·00290	0·00178
	(4)	0·00295	0·00194	0·00304	0·00193
M	(1)	0·00255	0·00150	0·00268	0·00152
	(2)	0·00270	0·00165	0·00274	0·00162
	(3)	0·00280	0·00176	0·00283	0·00173
	(4)	0·00297	0·00193	0·00299	0·00188
N	(1)	0·00253	0·00149	0·00270	0·00153
	(2)	0·00264	0·00161	0·00283	0·00166
	(2)	0·00278	0·00174	0·00295	0·00178
	(4)	0·00292	0·00189	0·00300	0·00188
O	(1)	—	—	—	—
	(2)	0·00258	0·00157	0·00265	0·00155
	(3)	0·00280	0·00175	0·00290	0·00175
	(4)	0·00306	0·00197	0·00308	0·00192
P	(1)	0·00248	0·00144	0·00266	0·00150
	(2)	0·00254	0·00153	0·00276	0·00161
	(3)	0·00272	0·00169	0·00290	0·00174
	(4)	0·00293	0·00188	0·00302	0·00188

thermal conductivity. It is thought advisable to emphasize that the present suggestion is that the thermal conductivity of the solid matter, *per se*, is increased by increasing the amount of burning to which the material is subjected. This is in direct contradistinction to any effect in decreasing the porosity which increase in the "burning" might have, with the consequent result (according to some investigators). of increasing the coefficient of thermal conductivity.

It must be mentioned that the above facts vitiate a direct and uncompromising comparison between the three batches, *i.e.*, between the effect of different sizes of grog, since the exact quantitative effect of this suggested variation in firing on the value of the coefficient of thermal conductivity is not known. However, the fact that there is only 0·00010 C.G.S. units (*i.e.*, about 6 per cent.) difference between the average conductivity of Batch II. and Batch I. indicates that the size of the grog in our experimental bricks does not have a very pronounced effect except in so far as this size controls the porosity and permeability.

The Effect of Porosity. It is obvious from the meaning of percentage porosity that if the true specific gravity of the material remains constant in any set of firebricks, the apparent

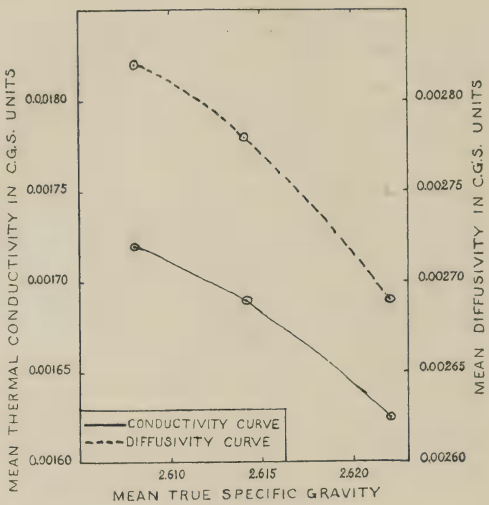


Fig. 6.

specific gravity must decrease with increasing porosity. Now since the product of the coefficient of diffusivity, the apparent specific gravity and the specific heat—which from a consideration of previous work on this constant , must be approximately the same in its values at different temperatures for all the experimental materials—gives the coefficient of thermal conductivity, it follows, that in order that the conductivity shall remain constant, when the porosity increases, the diffusivity must increase with increasing porosity in an exactly reciprocal manner, *i.e.*, the result should show that the product of the diffusivity and apparent specific gravity=a constant. Generally, the experimental data—up to temperatures of 1,000°C.—do not show that diffusivity increases with increasing porosity in the manner defined, with the consequence—particularly at these low temperatures—that the thermal conductivity decreases with increasing porosity. This is well illustrated in the previously-mentioned report on the conductivity of diatomaceous earth bricks in which it was shown that although the diffusivity of this material is only about 20 per cent. less than the diffusivity of firebrick, the conductivity is but one-third to one-fourth that of the same material. This is made evident by the fact that the apparent specific gravity of diatomaceous earth material is about two-fifths that of firebrick and that the porosity is two and a half to three times greater. Thus, in general, diffusivity measurements at lower temperatures indicate that with increasing porosity, decreasing thermal conductivity is to be expected.

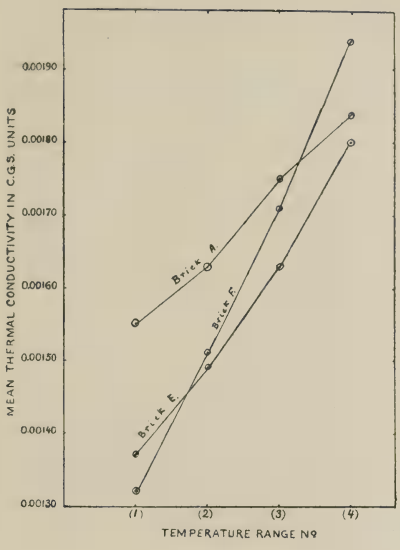


Fig. 7.

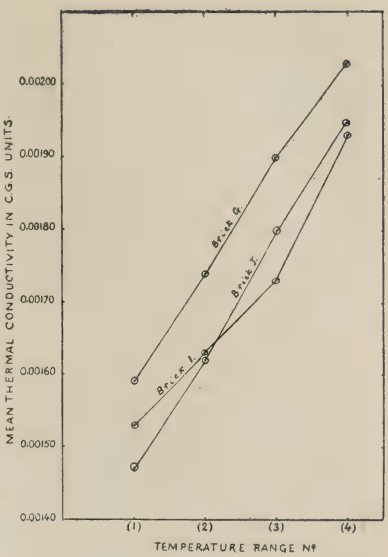


Fig. 8

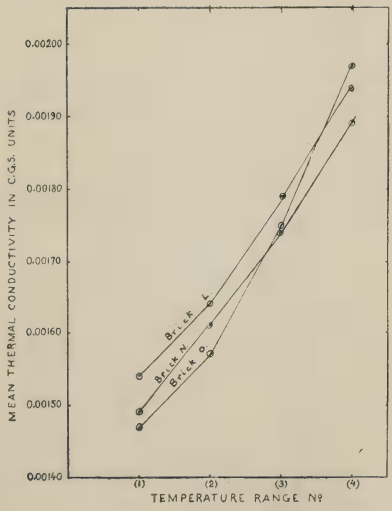


Fig. 9.

Compare now the reported values of brick *B* and brick *F*, of brick *L* and brick *O*. In each case the material with the higher grog content has the lower diffusivity and thermal conductivity for temperature range No. (1) than the lower grog material while at the highest temperature range No. (4) the reverse is the case. This is well shown in Figs. 7 and 9. Thus the fact that the material with a high grog content has a greater rate of increase of conductivity and diffusivity with temperature than the low grog material is well indicated. Fig. 8 for Batch II. material shows the rate of increase of thermal conductivity with temperature for the different grog-bricks, and although the comparison mentioned above in connection with the other two batches is not so pronounced, it is quite evident. With the object of showing more clearly this more rapid rate of increase of thermal conductivity with temperature as the grog content increases Fig. 10 is added. In this graph the difference between the conductivities reported for temperature ranges (1) and (4) is plotted against percentage grog content. For all batches there is shown a tendency towards the greater rate of increase of conductivity with temperature as the grog content increases. Batch I. indicates this in a decided manner. In fact, it is felt that the conductivity results reported for brick *F* are somewhat too high at the higher temperatures.

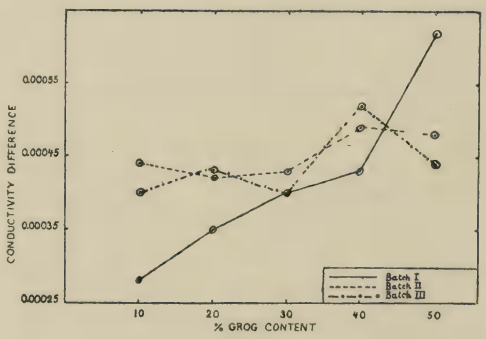


Fig. 10.

Consider Figs. 11 and 12. The former represents the average of the conductivities of temperature ranges (1) and (2), for each mark plotted against grog content, and the latter the average of temperature ranges (3) and (4) similarly plotted. The general interpretations of these two curves is similar to the one given for Fig. 10; the decrease in the conductivity with increasing grog content being more pronounced in the case of low temperature determinations than in the case of high temperature determinations. Fig. 12 shows the peculiar behaviour of the bricks in Batch I. at high temperatures, in which the conductivity apparently reaches a

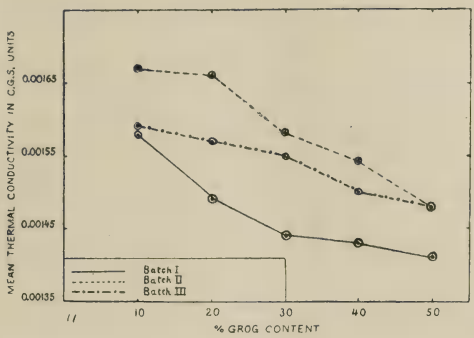


Fig. 11.

minimum at 30 per cent. grog. Since this does not altogether agree with what is noted in the case of the other two batches, it is suggested that there is possible some mal-observation in this result. In fact with Batch I., the decrease in conductivity from 10 per cent. to 30 per cent. grog and the increase from 30 per cent. to 50 per cent.

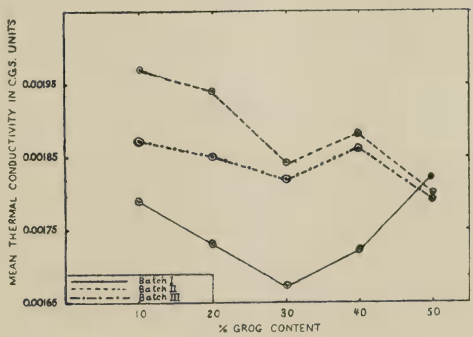


Fig. 12.

grog seem to be too great to be accounted for by the theory which follows. With allowances, however, this curve is amenable to a general consideration.

A Suggested Explanation.

A study of the results indicates one of two opinions, either (1) that the high grog content material, which, of course, possesses a higher porosity, has, at the high temperature of the experiment a higher diffusivity and thermal conductivity than the low grog material, or (2) that at somewhat higher temperatures than those of the experiment the higher grog content material

will have a higher thermal conductivity and diffusivity than that of the low grog material.

These indications are based on the results obtained from definite fired mixtures of grog and clay, in other words, either the grog of itself, or the effect of the grog on the texture of the brick causes this increase in the values of the conductivity and diffusivity. If the grog of itself, because it has received extra heat treatment and, therefore, possesses a higher thermal conductivity is the cause, then it must be expected that the conductivity of high grog material at low temperatures must be higher than the conductivity of low grog material at the same temperatures. This is by no means the case, the conductivity of the high grog material being, in practically all cases, lower than the conductivity of low grog materials at low temperatures. Thus for temperature range (1) the conductivity of brick *A* is 0·00155, but for brick *F* it is 0·00132, for brick *L* with the same temperature range it is 0·00154, for brick *P* it is 0·00144. It may thus be argued with confidence that the effect of the grog of itself is not the cause of the observed comparatively higher conductivity values of the high grog materials at high temperatures.

The effect, then, is concerned obviously with the alteration of the texture of the materials by the grog, and further, with some noticeable alteration in the behaviour of the pore spaces. Thus the conclusion is reached that heat is transmitted, in appreciable quantities, by way of the pores. Such a transmission can consist of one or both of two phenomena, *i.e.*, radiation and convection. Considering the former, the calculation mentioned in the introduction and put forward in a previous paper[3], showed that with pore-spaces less than 0·005 cms. across in the direction of the heat flow had a practically negligible effect. However, with such pores of greater width than 0·02 cms., the probability of an effective heat transmission by radiation at temperatures over, say, 1,150°C. is very pronounced. The materials under investigation—particularly those containing the higher grog contents—could be seen actually to possess many elongated pores, situated in such a manner as to be almost in the direction of the heat flow in the experiments. In this investigation, the observed rapid increase in the thermal conductivity of the high grog material is, in part, probably due, then, to a radiation effect.

Convection effects are also likely to occur. The extent of such effects will be dependent, in no small measure, on the relative permeability of the material to gases. This property is somewhat connected with porosity, in so much as the distinguishing feature of permeability is a continuity of pore, allowing a direct, and, more or less, unimpeded passage for gases under pressure. Permeability thus depends on the number of channels or connected pores, which enable the permeating fluid to pass through. The following figures, reported by Queneau,[6] illustrate the distinction

between porosity and permeability.

Material	Percentage Porosity	Relative Permeability
Firebrick	30·85	14·7
Firebrick	30·20	106·2

It is thus easy to conceive of great differences in the permeabilities of the high grog bricks of our experiments as compared with the low grog bricks. The percentage porosities, however, do not differ by 5 per cent.

Considering a brick of relatively high permeability, first we see that, under the conditions of our experiment, the air in the pores at the hot face end, becomes highly heated, and of a consequence, possesses a decided mobility. This gives rise to convection currents within the pores of the brick which currents have a greater range of effect in the case of materials of greater permeability. In its transit this air gives heat to the solid particles increasing their temperatures above that value, which would result from pure conduction through the solid matter. Such heat gain and heat loss by convection is proportionel to T^n where T is the difference in temperature between the heating gas and the surface of the particle being heated, and n is an index probably greater than 1. For heat losses by natural convection at low temperature $n=1\cdot25$ (Griffiths)[7], but there is reason to believe from the work of Langmuir[8] that n for convective losses approximates to 1·6 as the temperature reaches 1,450°C. Little or no reliable data circumscribing the actual transference of heat from a gas at a high temperature (over 1,000°C.) to a surface have been published, but theory points to an enhanced convective heating at high temperature.

The net result of the convective effect of hot air in the pores of the brickwork must be that the temperature at different points in the brick will be raised, with a consequent effect on the temperature gradients. Under the conditions of the above experiment an approximate equilibrium will be reached between the hot air and the hot solid matter, after a certain time has elapsed. Since the rate of rise of temperature at the first hole is rarely more than 12°C. per hour after a time of 8 hours from the commencement, it is thought that, at this period, a sufficiently approximate equilibrium has been established.

Howe and Phelps[9] have thrown some light on the quantitative effect of heating by convection, when the hot gases are drawn through brickworks under pressure. Although their results cannot be directly introduced into the above argument, they indicate the effect of hot gases on the temperature gradients in firebricks. The reported results of these investigations—a selection of which is appended in Table V.—

TABLE V.

Furnace Temp.	1,340°C.	1,340°C.	1,340°C.	1,220°C.	1,220°C.
Pressure of Furnace Gases (inches of water)	+1·00	+0·05	—0·30	+0·95	+0·05
Temp. of firebrick ½″ from hot face ..	1,305°C.	1,265°C.	1,105°C.	1,105°C.	1,075°C.
,, ,, 1″ ,, ,, ,, ..	1,270°C.	1,210°C.	1,020°C.	1,035°C.	965°C.
,, ,, 2″ ,, ,, ,, ..	1,125°C.	1,040°C.	800°C.	900°C.	770°C.
,, ,, 3″ ,, ,, ,, ..	1,040°C.	950°C.	720°C.	800°C.	660°C.

It appears, therefore, that convection plays an important part in heat transmission through relatively permeable firebricks.

The passage of heat by conduction is affected by the degree of continuity of solid matter existing in the material. It is obvious then that the semi-vitrified nature of bricks *A*, *B*, *G* and *L* gives the bricks a power for pure conduction greater than those which have had this continuity interrupted by grog. Thus, when the transmission of heat is in the main, the result of pure conduction, *i.e.*, at low temperature, such a low-grogged material will show a higher determined coefficient of thermal conductivity. This is in accordance with the results (*vide* Fig. 7, 8 and 9). However, the rate of increase of heat transference by conduction through the solid matter with temperature at high temperatures does not appear to be so great as the rate of increase in the transmission of heat by convection and radiation in the pore-spaces, with the result that the two latter effects overtake in value at some high temperature, the conductive effects. This, therefore, accounts for the more rapid increase with temperature in the observed value for the coefficient of thermal conductivity of the high grog bricks at high temperatures.

NOTE ON THE TRANSMISSION OF HEAT THROUGH SILICA BRICKS.

It has been stated, on many occasions, that silica bricks have a higher value for thermal conductivity than firebricks. The present investigator has been unable to obtain complete comfirmation for such a generalization in his experimental work. As a matter of fact, in a number of investigated cases there appears to be little difference between the diffusivities of silica bricks and firebricks at temperatures below 1,000°C. In a few other cases the diffusivity of the silica brick is higher than the diffusivity of an average firebrick below 1,000°C. Since the heat capacity per unit volume is greater in the case of firebricks than silica brick, it appears that, in some of the investigated cases, the thermal conductivity of silica brick is slightly less then that of firebrick at temperatures below 1,000°C. However, the author has noted that the rate of increase of temperature diffusivity, and, consequently, of thermal conductivity, is decidedly greater in the case of three well-burned silica bricks than those of an average firebrick material at a temperature of about

1,200°C. This suggests that the thermal conductivity of silica bricks is greater, at modern high temperatures of working than that of firebricks. Of course, it is essential to investigate these facts, in the light of the texture, the "firing", and other properties of the material, before any conclusions concerning the increased transmission of heat through the pores of the silica material can be stated.

An interesting fact bearing on the behaviour of the pores in industrial practice, has been brought forward by Dale[10]. He notes that in general, the effect of pressure at high temperatures (1,300-1,400°C.) is to reduce the porosity of a fireclay refractory considerably (in some cases from 20% to 5%) ; whereas, similar conditions have little effect on the porosity of a 95% silica brick. It is probable, then, that any transmission of heat by way of the pores, will be maintained in silica constructions, whereas in fireclay units such transference may be considerably reduced. Herein may lie a clue to the generally-accepted opinion that silica bricks conduct heat better than firebricks, under modern industrial conditions.

Summary.

(1) Batches of bricks containing varying proportions and grades of grog, and of almost identical "material factor" have been made.

(2) The true and apparent specific gravities, the true and apparent porosities, and the crushing strengths of these batches gave been investigated, and certain relationships found to subsist.

a) The effect of additions of grog on the true specific gravity of the fired material is noted, and, consequently, the influence of "firing" on the true specific gravity of the fired material, when the "burning" is in the vicinity of Cone 10, is suggested.

(*b*) The effect of increasing grog content on the crushing strength and porosity is indicated.

(*c*) The influence of grog content on the texture, and, consequently, on the "permeability to gases" of the material is suggested.

(3) The temperature diffusivity and thermal conductivity of all the batches, over a range of temperatures, varying from a temperature range of 920°-610°C. (approximately) and 1,270°-870°C. (approximately) have been investigated

(4) The effect of "firing" on the thermal conductivitity of the solid material, *per se*, is discussed.

(5) From a point of view of the determined data of thermal conductivity the effect of porosity and permeability to gases, is discussed. It is considered that the transmission of heat

by way of the pores spaces, by the phenomena of convection and radiation, takes place in quantities comparable with that by way of conduction through the solid matter at the higher temperatures of experiment.

(6) Transmission by means of convection, it is suggested, takes place to a much greater extent, in the more permeable bricks, *i.e.*, the bricks of higher grog content. A brief discussion of the permeability of firebricks is included.

(7) A discussion of the thermal conductivity of silica bricks, based on some experimental data and the behaviour of silica bricks in practice, is included.

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XXI.—The Thermal Conductivity and some other Properties of two Commercial, Heat-Insulating Bricks used in Kiln Construction.*

By A. T. Green.

[Communication from the Clay and Pottery Laboratory, Stoke-on-Trent, No. 111].

RECENT investigations of the thermal efficiencies of kilns have shown definitely the amount of heat lost by way of the kiln walls. Thus, Harrop[1] indicated that with a certain continuous tunnel kiln a loss, by such causes, of some 45 per cent. of the total fuel fired, is experienced. Bleininger[2], in an investigation of three commercial kilns, noted a loss, through the walls of 25 per cent. of the total fuel fired. A suggestion aiming at the reduction of this loss was made in 1905, by Hutton and Beard , who proposed placing a layer of highly non-conducting material between the interior firebrick lining and the exterior casing of the kiln or furnace. For such a purpose, light-weight, heat-insulating materials are now being used in increasing quantities and are responsible for much greater thermal efficiencies in many furnace operations. Bleininger, in the above-mentioned work, estimated that 60-70 per cent. of the heat lost through the walls could be prevented by the use of such methods.

Accordingly, this paper chiefly sets down the results of experiments, with two batches of commercial heat-insulating material, undertaken to determine the thermal conductivity and a few other properties of a practical significance.

The Material of Experiment.

The principal constituent of the experimental bricks is kieselguhr, which is also known by the names, diatomite, diatomaceous earth and infusorial earth. It is a light, very porous earth which consists of the silicious remains of minute organisms, together with a considerable quantity of earthy impurities. Deposits of this material are widely distributed in nature. The earths used in the bricks for the present investigations were obtained from the North of Ireland (Batch A), and from Algeria (Batch B). Good accounts of the deposits and general characteristics of diatomaceous earth are given by Goodwin[4], Charpentier[5], and Manzella[6].

In the case of the bricks of Batch A, the earth was mixed with 15 per cent. of cork and sawdust ; mixed and moulded by hand and fired to about 850°C. The bricks of Batch B were manufactured

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by mixing about 15 per cent. of sawdust and 10 per cent. of clay with the earth. These ingredients were mixed in an open mixer, moulded by hand and fired to about the same temperature. Sawdust is added to maintain the high porosity of the diatomaceous earth. Other light-weight refractories used for insulation purposes are also manufactured from mixtures of clay and sawdust. In this connection, it is interesting to note that Beecher[7] has established the fact that 40 per cent. of sawdust is the practical limit for good working with a plastic clay. The practical limit, when working with diatomaceous earth, must be a much lower percentage of sawdust.

TABLE I.

Analysis of the Experimental Bricks.

Batch	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss on Ignition
A	73·07%	n.d.	16·62%	5·00%	0·98%	0·33%	1·10%
B	76·70%	0·62%	13·60%	0·87%	5·66%	1·32%	0·90%

RESULTS.

TABLE II.

Mark	Temp. Range	Mean Diffusivity in C.G.S. units	Mean Thermal Conductivity in C.G.S. Units
A_1	511°–290°C.	0·00144	0·00025(5)
	647°–380°C.	0·00156	0·00030
	766°–470°C.	0·00174	0·00036
A_2	511°–180°C.	0·00151	0·00026
	647°–244°C.	0·00167	0·00030
	766°–308°C.	0·00181	0·00035(5)
B_1	580°–334°C.	0·00170	0·00030
	774°–469°C.	0·00193	0·00038
	840°–502°C.	0·00193	0·00039
B_2	580°–236°C.	0·00171	0·00029
	774°–318°C.	0·00190	0·00035
	840°–356°C.	0·00198	0·00039
B_3	580°–346°C.	0·00175	0·00031
	647°–390°C.	0·00183	0·00033(5)
	774°–464°C.	0·00183	0·00036
	840°–514°C.	0·00194	0·00039
B_4	580°–238°C.	0·00177	0·00030
	647°–272°C.	0·00180	0·00031(5)
	774°–324°C.	0·00189	0·00035(5)
	840°–360°C.	0·00194	0·00038

TABLE III.

Mark	True Sp. Gr.	App. Sp. Gr.	Percentage Porosity	Crushing Strength	Refractory Test
A	2·57	0·73	71·6	286 lbs. per sq. in.	Cone 7 (1,230°C.)
B	2·61	0·69	73·5	338 lbs. per sq. in.	Cone 8 (1,250°C.)

METHOD OF EXPERIMENT.

The method of experiment has been described in a previous paper[8]. Essentially, it consists of the maintenance of an even and constant temperature on the hot face of a wall of the material from the beginning to the end of an experiment, and the accurate measurement of the rate of rise of temperature for any isothermal plane at a known distance from the hot face. From the data so obtained the diffusivity and, subsequently, the conductivity are computed. Besides the conductivity, the crushing strength, porosity, specific gravity and refractoriness of the material were determined.

DISCUSSION OF RESULTS.

A_1 and A_2 represent the results obtained with one brick specimen from Batch A, by the computation of the time-temperature measurements from two isothermal planes at distances of about 5 cms. and 8 cms. respectively from the hot face. Two separate experiments with two different bricks from Batch B were realized, hence the two series B_1 and B_2; B_3 and B_4. As before, B_1 and B_3 were about 5 cms., and B_2 and B_4, about 8 cms. distant from the hot face. It will be noticed that the results agree well, although the diffusivities obtained from the 8 cms. holes are, in general, slightly higher than those obtained from the 5 cms. holes. This fact has been noted in a previous report on the conductivity of refractory materials[8].

Table IV. is included for purposes of comparison. The results obtained by Griffiths[9] are somewhat higher than those given in Table II. Boeck[10], reporting the properties of Sil-O-Cel, a comparable material, gave 0·5–0·9 B.Th.U's per sq. foot per hour per °F. difference in temperature, between ordinary temperatures and 1,000°F. These values correspond to a conductivity of 0·00017–0·00027 C.G.S. units at about 400°C. Such data are slightly lower than those obtained by the present author, which agree well, however, with Nusselt's results. Again, comparing the data given in this paper with those recently obtained by the author for the conductivity of a Stourbridge fireclay brick, it may be pointed out that the conductivity of the insulating materials A and B is about one-fourth that of this firebrick at a temperature of about 500°C.

TABLE IV.

Results obtained from previous investigations with comparable materials.

Material	Temp.	Thermal Conductivity in C.G.S. Units	Authority
Kieselguhr mixed with small amount of clay and fired to 900°C. (approx.)	500°C.	0·00046	Griffiths[9]
Sil-o-Cel; an American Commercial product	300°C.	0·00017 to 0·00027	Boeck[10]
Kieselguhr (loose)	0°C. 100°C. 400°C.	0·000144 0·000183 0·000219	Nusselt[11]
Kieselguhr (baked)	0°C. 400°C.	0·000178 0·000333	Nusselt[11]

The refractoriness of both materials A and B is very low. Moreover, with material A there is a very defined shrinkage commencing at 900°C. The action indicated by this shrinkage, results in a great increase in the conductivity of the material. Thus, after heating the face of the brick for 20 hours at about 1,120°C. the conductivity, calculated from the temperature readings of a hole 5 cms. from the hot face, becomes 0·00061 between 896–627°C. This shrinkage is obviously due to an incipient fusion resulting from the presence of fusible impurities. When the material is required for very high temperature insulation, some purification of the original earth should be adopted, if possible, so that a brick containing at least 92 per cent. of silica, results. In practice, however, the hot face of the insulating material does not, usually, exceed 800°C., so that many impure diatomaceous earths can be used efficiently. In this connection it must be noted that in modern kiln construction the use of insulating material is resulting in the design of thinner kiln walls. This emphasizes the fact that wherever the walls are so designed, diatomaceous bricks of good quality must be used, since the face temperature of the insulation wall will, in these circumstances, be much higher.

It is very desirable to maintain an unimpaired wall of insulating brick covering the outer surface of the kiln walls. To do this, the insulating material must possess a good mechanical strength, since the expansion and contraction of the kiln walls give rise to very considerable strains, which are exerted on the insulation wall. Boeck states that a crushing strength of 400 lbs. per sq. in. is a very satisfactory indication of the required mechanical strength. From the nature of the material—*i.e.*, the high porosity which must be maintained in manufacture, etc.—a

crushing strength much higher than 400 lbs. per sq. in. cannot be expected.

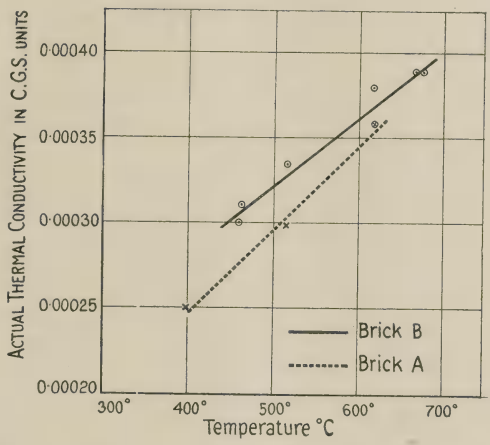

Fig 1. Variations of Actual Thermal Conductivity with Temperature.

The great insulating properties of the material are due to the presence of an infinite number of minute pores which are part of the organic remains of the diatomite. In fact, the structure can be conveniently regarded as an air space divided into an infinity of air cells by a minimum of solid matter. Physical reasoning indicates that the heat transmission by radiation and convection across this air space is considerably lessened in consequence of this peculiar structure. The limit of the effect of this division of the air space must be reached when the heat transmission across the pore spaces approximates in quantity almost to the likely value for the conductivity of air. The conductivity of air is given as 0·000058 C.G.S. units at 55°C., and although no data are given for this constant at higher temperatures, it is probable that the value will be, at least, one-twelfth the conductivity of the solid material at, say, 500°C. At lower temperatures and with a maximum of pore spaces of minute size, the transmission of heat by way of these pore spaces may, indeed, approximate to an air conduction. Such an explanation appears to cover the insulating properties of diatomaceous earth. However, a similar reasoning should not be followed too closely in the case of grogged fireclay bricks where the pores —some of them, at least—are by no means microscopic and the temperatures of practice, to which they are subjected, are much higher.

Finally, porosity or apparent specific gravity may be used as a rough guide to the insulating properties of diatomaceous earth bricks. A brick with a percentage porosity of 70–80 per cent.

or an apparent specific gravity of 0·55 to 0·7 will, in general, be a satisfactory insulator.

The author wishes to thank the Derbyshire Silica Firebrick Co. for the help and privileges they have extended in connection with this investigation.

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XXII.—Note on Alkaline Casting Slips.

By F. S. Worthington.

A series of experiments has recently been carried out, indicating that the amount of contraction, to which cast ware is subject in the biscuit oven, is dependent upon the weight of solid matter per pint in the casting slip. In the course of actual works practice, a number of six-pint jugs were cast in the ordinary way, but, after firing, some of these jugs showed the surprising capacity of $6\frac{3}{4}$ pints. There was no difference in the colour of the ware, and the firing temperature was judged to be about the same for all the jugs. Consequently, the explanation had to be sought elsewhere.

The moulds were filled with slips varying from 30 oz. to 36 oz. to the pint, and the ware was fired in one saggar in the biscuit kiln. Again a difference in size was noted; the jugs cast with slip at 30 oz. to the pint were much larger than those made with the 36 oz. slip.

At a recent meeting of the Pottery Managers' Association, Mr. Bernard Moore stated that ware cast with light slip was more liable to craze than ware cast with a heavier slip. In order to test this, the trials were again repeated, using on this occasion slips at 30 and 34 oz. to the pint. The results of this test showed that the ware cast with the heavier slip contracted 10 per cent., and lost in weight 26·49 per cent, whilst the ware cast with slip at 30 oz. to the pint contracted only 8·8 per cent., but lost 30 per cent. in weight. The heavy slip cast up in 13 minutes, but the light slip required 35 minutes to produce ware of about the same thickness. The temperature in the biscuit kiln was 1,165°C. Three such series of trials have been made during the last two years, and in each case, the ware cast with light slip showed least contraction.

XXIII.—The Behaviour of Clays, Bauxites, etc., on Heating. III.

By

H. S. Houldsworth, M.Sc. and J. W. Cobb, C.B.E., B.Sc., F.I.C.

(Fuel Department, the University, Leeds).

PART 7.

(*A*) Thermal Phenomenon observed on Heating Minerals which may occur in Clays.

It was thought that some of the smaller shrinkages and other effects observed on heating clays (see Part I) might be due to the interaction of the impurities present in the clays with the clay substance, or in some cases to changes in the impurities themselves. Moreover, such substances are deliberately added in the compounding of ceramic and other mixtures, and have their own interest on that account. Accordingly, the thermal phenomena shown on heating various minerals which may be present in clays, both alone and when mixed with an equal weight of kaolin, were determined by the method described in Part 3.

RESULTS OBTAINED.

(*a*) *Felspars*. Albite ($Na_2O.Al_2O_3.6SiO_2$), orth clase ($K_2O.Al_2O_3.6SiO_2$), anorthite ($CaO.Al_2O_3.2SiO_2$), and labradorite (Ab_2An_3) showed no thermal phenomenon on heating alone to 1,000° and the only thermal changes noted on heating each of these minerals mixed with an equal weight of kaolin were at 500° and 950° *i.e.*, at the points where the kaolin was undergoing changes.

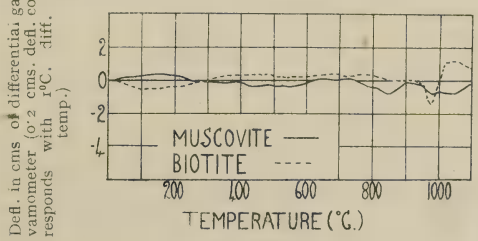

Fig. 1.

(*b*) *Micas*. (See Fig.1) *Muscovite* ($K_2O.3Al_2O_3.6SiO_2.2H_2O$) was heated to 1,100° and gave a slight irreversible heat absorption at 810° (completed at 850°), due to dehydration and a possible

decomposition into leucite and sillimanite ($K_2O.3Al_2O_3.6SiO_2$ $2H_2O \rightarrow K_2O.Al_2O_3.4SiO_2 + 2(Al_2O_3.SiO_2) + 2H_2O$.* No new thermal phenomena suggesting interaction with kaolin was detected by this method on heating a mixture of mica and kaolin. *Biotite* [$K_2O.4(MgFe)O.2(Al.Fe)_2O_3.6SiO_2.H_2O$] showed on heating to 1,100°. an irreversible endothermic reaction at 950° (completed at 975°), due presumably to decomposition of the biotite as dehydration occurred at 710° (see Part 8). No interaction with kaolin was detected by this method.

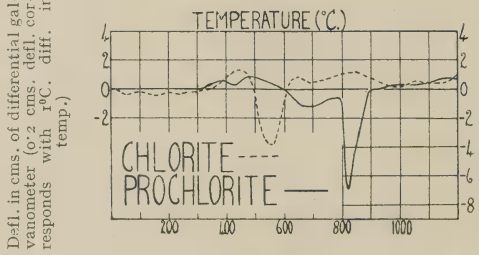

Fig. 2.

(*c*) *The Chlorites*. (See Fig. 2) *Chlorite* (a complicated hydrated silicate of aluminium, iron, and magnesium) had only one thermal change on heating alone to 1,200° viz. an irreversible heat absorption starting at 465° and completed at 550° No thermal phenomenon indicative of interaction with kaolin was observed on heating a mixture of chlorite and kaolin.

Prochlorite [$23(MgFe)O.7Al_2O_3.13SiO_2.20H_2O$] underwent an irreversible endothermic change at 790° (completed at 820°) on heating, due to dehydration. No other change was observed up to 1,200°, and no interaction with kaolin was detected by this method.

(*d*) *Iron Compounds*. (See Fig. 3). Limonite ($Fe_2O_3.nH_2O$) showed only one thermal change on heating to 1,000°, viz., an irreversible heat absorption at 325° (completed at 370°.) due to dehydration. No new thermal phenomenon was observed on heating with kaolin.

Siderite ($FeCO_3$) gave some very interesting results. A very large absorption of heat took place at 465° (completed at 563°.) due to the decomposition of the carbonate. This was followed by a large evolution of heat at 694° (completed at 760°) and a further, but considerably smaller, exorthermic effect at 785° (completed at 820°). No further change was observed on heating to 1,200° and all the changes were irreversible. No interaction accompanied by thermal changes of siderite with kaolin was observed in these experiments.

* Doelter (*Neues Jahrb.*, **1**, 1, 1897) found leucite and Vernadsky (*Min. pet. Mitt*, **18**, 1898, p. 26) sillimanite among the fusion products of muscovite.

(*e*) *Calcium Carbonate.* Iceland spar ($CaCO_3$) showed an irreversible heat absorption starting at 745° (completed 940°) due to decomposition of the carbonate. The change was slow at first, and only became pronounced at 800°. No other thermal change was detected up to 1,200°. No thermal phenomenon indicative of interaction of Iceland spar with kaolin was observed on heating a mixture of the two.

(*f*) *Titania.* Rutile (TiO_2) exhibited no thermal change on heating to 1,200°, and no thermal phenomenon not characteristic of kaolin alone was found on heating a mixture of rutile and kaolin.

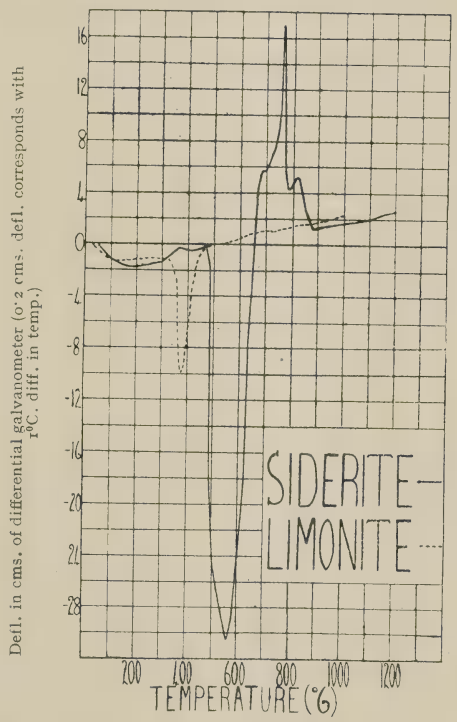

Fig. 3.

(*g*) *Minerals containing magnesia.* (see Fig. 4). *Serpentine* (after olivine) $2(MgFe)O.SiO_2.H_2O$ experienced an endothermic reaction at 585° (completed 670°) which corresponded with the dehydration of the mineral (see Part 8), and an exothermic change at 795° (completed at 825°). No other thermal changes were found up to 1,100°, and no heat absorptions or evolutions not previously found with kaolin or serpentine alone were detected on heating a mixture of equal parts of these minerals.

Talc, $3MgO.4SiO_2.H_2O$, gave a small irreversible heat absorption at 985° (completed at 1,015°) due to liberation of water and possibly decomposition into enstatite and silica thus :—

$$3MgO.4SiO_2.H_2O = 3MgO.SiO_2. + SiO_2 + H_2O^*.$$

It showed no other change on heating to 1,100°, and no interaction with kaolin was detected by this method.

Enstatite ($MgO.SiO_2$) was studied as a possible decomposition product of serpentine and talc. It showed no thermal phenomenon on heating to 1,200°, while a mixture of enstatite and kaolin showed only the thermal changes characteristic of kaolin alone.

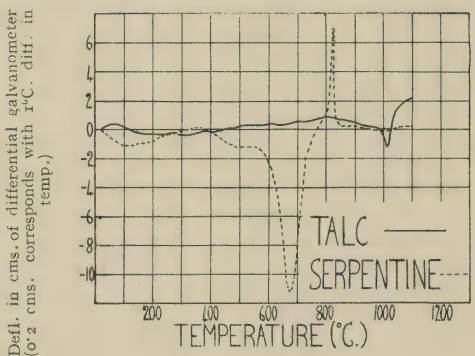

Fig. 4.

The identity of the results obtained by testing the minerals separately and in admixture with kaolin discloses a complete absence of any evidence of interaction. The results obtained for the minerals selected show that the hydrated micas are dehydrated (or undergo other decomposition) at different temperatures with absorptions of heat, and so may exercise slight disturbing effects upon the thermal phenomenon observed for clays. But the nature and magnitude of the effects observed, coupled with a consideration of the small quantities of the minerals normally found in clays, would justify the conclusion that, in probably every case examined and reported in the preceding parts of this paper, the phenomena were inherent in the clays and not due to the interference of the mineral impurities (other than hydrated aluminum silicates) present.

(B) Ashley† has suggested that the evolution of heat observed about 980°. on heating a clay was due to the possible formation of sillimanite from the alumina and silica set free by the decomposition of the clay about 500°. In order to test this point as far as possible by means of heating curves, various finely ground

* Clarke *Data of Geo-Chemistry*, p. 608.
† *J. Ind. Eng. Chem.*, 3, 91, 1911.

intimate mixtures of alumina and silica were prepared of the composition $Al_2O_3+2SiO_2$ as follows :—

(i.) Precipitated alumina[2] + silica glass (vitreosil).
Precipitated alumina[2] + precipitated silica[1] (from silicon fluorite).
Precipitated alumina[2] + pure quartz sand.
(ii.) Alumina[2] (from aluminium nitrate) + silica glass (vitreosil).
Alumina[2] (from aluminium nitrate) + precipitated silica[1] (from silicon. fluoride)
Alumina[2] (from aluminium nitrate) + pure quartz sand.

TABLE. I.

Felspars.				
Albite ..	$Na_2O.Al_2O_3.6SiO_2$	No thermal changes		
Orthoclase ..	$K_2O.Al_2O_36SiO_2$			
Anorthite ..	$CaO.Al_2O_3.2SiO_2$			
Labradorite	Ab_2An_3			
Micas.				
Muscovite ..	$K_2O.3Al_2O_3.6SiO_2$ $2H_2O$	Heat absorption 810°	Completed	850°
Biotite ..	$K_2O.4(MgFe)O.$ $(2AlFe)_2O_3$ $6SiO_9H_2O$	Heat absorption 950°	,,	975°
Other Minerals				
Chlorite ..	a complicated hydrated silicate of aluminium, iron, and magnesium	Heat absorption 465°	,,	550°
Prochlorite ..	$23(MgFe)O.$ $7Al_2O_3$ $13SiO_2.20H_2O$	Heat absorption 790°	,,	820°
Limonite ..	$Fe_2O_3.xH_2O$	Heat absorption 325°	,,	370°
Siderite ..	$FeCO_3$	Heat absorption 465°	,,	563°
		Heat evolution 694°	,,	760°
		Heat evolution 785°	,,	820°
Iceland Spar	$CaCo_3$	Heat absorption 745°	,,	940°
Rutile ..	TiO_2	No thermal changes		
Serpentine ..	$2(MgFe)O.$ SiO_2H_2O	Heat absorption 585°	,,	670°
		Heat evolution 795°	,,	825°
Talc ..	$3MgO.4SiO_2.H_2O$	Heat absorption 985°	,,	1015°
Enstatite ..	$MgO.SiO_2$	No thermal phenomenon		

1 Previously dehydrated at 400°C
2 Previously calcined at 700°C

In no case was an evolution of heat detected in the neighbourhood of 950°, so that no evidence was obtained from these experiments in support of Ashley's assertion.

Samoilov* considered that a special form of allophane ($Al_2O_3.SiO_2$) and SiO_2 were produced by the decomposition of the clay at about 500°. The evolution of heat at 950° would thus be due, presumably, to changes in the allophane or silica or to a recombination of the two. No heat evolution was found about 950° on heating allophane alone (see Part 3), and silica shows no thermal phenomenon at this point. In order to test this theory as fully as possible by thermal experiments, various finely ground intimate mixtures of the composition $Al_2O_3.SiO_2+SiO_2$ were prepared as follows :—

(i.)	Sillimanite	($Al_2O_3.SiO_2$)	+ silica glass (vitreosil).
	Sillimanite	($Al_2O_3.SiO_2$)	+ precipitated silica[1] (from silicon fluoride).
	Sillimanite	($Al_2O_3.SiO_2$	+ pure quartz sand.
(ii.)	Cyanite	($Al_2O_3.SiO_2$)	+ silica glass (vitreosil).
	Cyanite	($Al_2O_3.SiO_2$)	+ precipitated silica[1] (from Silicon fluoride).
	Cyanite	($Al_2O_3.SiO_2$)	+ pure quartz sand.
(iii.)	Andalusite	($Al_2O_3.SiO_2$)	+ Silica glass (vitreosil).
	Andalusite	($Al_2O_3.SiO_2$)	+ precipitated silica[1] (from silicon fluroide).
	Andalusite	($Al_2O_3.SiO_2$)	+ pure quartz sand.
(iv.)	Allophane[3]	($Al_2O_3.SiO_2.5H_2O$)	+ silica glass (vitreosil).
	Allophane[3]	($Al_2O_3.SiO_2.5H_2O$)	+ precipitated silica[1] (from silicon fluoride).
	Allophane[3]	($Al_2O_3.SiO_2.5H_2O$)	+ pure quartz sand.

No evolution of heat was detected with any of these mixtures at 950° so that these experiments gave no support to Samoilov's theory.

Part 8.

LOSS IN WEIGHT ON RAPID HEATING. THE RELATION BETWEEN LOSS IN WEIGHT AND THE ENDOTHERMIC REACTIONS.

It was found in the experiments described in Parts 2 and 3 (Trans. **22**, 111, 1923), that a difference of 80° or more existed between the temperatures at which clays, bauxites, etc., experienced a loss in weight and those at which endothermic reactions were observed. It has to be remembered, however, that differential heating curves must necessarily be taken at a somewhat rapid rate of heating (7-8° per minute was selected for our experiments), while the curves for the losses in weight were obtained on heating

* *Bull. Acad. Imp Sci.*, **11**, 779, 1914).

[3] Previously heated in furnace to 900°C. to complete dehydration.

very slowly. It was conceivable, therefore, that the temperatures at which losses in weight took place would be raised on rapid heating, and accordingly the loss in weight experiments were repeated with the temperature rising at 8° per minute as in the differential heating tests. Similar experiments were made with the minerals used in Part 7. The results obtained are shown graphically in Figs. 5, 6, 7, 8, and 9. The temperatures at which losses in weight started under slow and rapid heating, and those at which endothermic reactions were observed are collected in Table II. It will be seen that the temperatures at which the substances began to lose weight have been raised by 80° or more by rapid heating, and that the *temperatures determined in this way agree very well with the temperatures at which endothermic reactions started* when the materials were heated at the same rate.

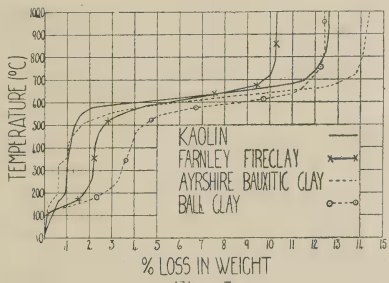

Fig. 5.

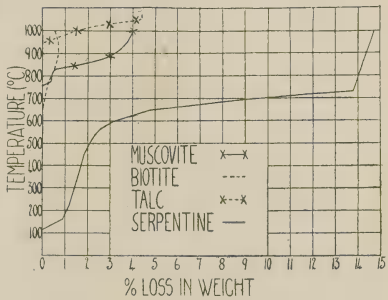

Fig. 8.

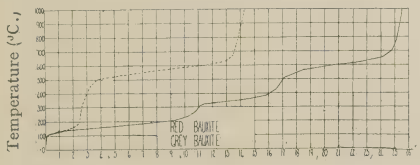

Fig. 6.

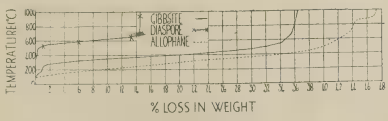

Fig. 7.

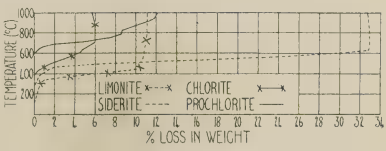

Fig. 9.

In nearly all cases the endothermic reactions observed were due to changes such as dehydration, or decomposition of a carbonate, which involved a loss of weight. Cyanite, ($Al_2O_3.SiO_2$), however,

TABLE II.

Temperature at which losses in weight and endothermic reactions are observed.

Substance	Chemical Formula	Loss in Weight: Slow heating (°C.)	Loss in Weight: Rapid heating (°C.)	Endothermic reactions
Kaolin ..	$Al_2O_3.2SiO_2.2H_2O$	420-450	500	500
			100	90
Farnley fireclay		425-450	480	510
Ayrshire bauxitic clay		15-90 } slight	100 } very slight	
		220	320	
		320-390 }	420 }	
		400-470	490	530
Ball clay ..		n.d.	110	110
			480	500
Red bauxite ..		350-410	90	
			500	490
Grey bauxite ..		200-220	90	upto 180
		390-450	310	310
			510	510
Gibbsite ..	$(Al_2O_3.3H_2O)$	160-190	230	240
Diaspore ..	$(Al_2O_3.H_2O)$	370-400	490	470
Allophane ..	$Al_2O_3.SiO_2.5H_2O$	120-180	110	50 (started slowly)
		230-280	320*	270
		670-820	840	860
Pyrophillite ..	$Al_2O_3.4SiO_2.H_2O$	n.d.	490 slight	
			710	720
Halloysite (?) ..	$Al_2O_3 \cdot 2SiO_2$ $2H_2O.Aq.$	n.d.	From 15°C.	50
			470	490
Silica (precipitated containing soda)	$SiO_2.xH_2O +$ soda	not done		80
Silica (from silicon fluoride)	$SiO_2.2H_2O$	Only very slight loss in weight after previously heating at 70°C. for long period		
Alumina (precipitated)	$Al_2O_3.xH_2O$	From room temperatures with increases in weight at 100° and 200°	90	70
			330*	365
Muscovite ..	$K_2O.3Al_2.O_3.$ $6SiO_2.2H_2O$	n.d.	820	810
Biotite ..	$K_2O.4(MgFe)O.$ $2(AlFe)_2O_3$ $6SiO_2.H_2O$	n.d.	710	950
Talc ..	$3MgO.4SiO_2.H_2O$	n.d.	950	985
Serpentine ..	$(2MgFe)\ O.SiO_2$	n.d.	570	585
Limonite ..	$Fe_2O_3.n.H_2O$	n.d.	320	325
Siderite ..	$FeCO_3$	n.d.	450 (began very slowly at 400)	465
Chlorite ..	Hydrated silicate of Al, Fe and Mg.	n.d.	400 (completed 630)	390
			700	465
Prochlorite ..	23 $(MgFe)O.$ $7Al_2O_3$ $13SiO_2.20H_2O$	n.d.	600	
			820	790
Iceland spar ..	$CaCO_3$	n.d.	700 slowly	745

* Temperature at which rate of decrease in weight increased.

had an endothermic reaction at 775°, which obviously cannot be associated with a decrease in weight. Biotite decreased in weight at 710°, whilst the only endothermic reaction it experienced occurred at 950°. It will be seen, however, that with these two (unexplained) exceptions (cyanite and biotite), all the absorptions of heat which were detected corresponded with a decrease in weight. Chlorite, a complicated hydrated silicate of aluminium, iron, and magnesium, showed two endothermic reactions at 390° and 450°; it began to lose weight at 400°, and this continued to 630°. It was not possible to divide this decrease in weight on rapid heating into two portions. Chlorite and prochlorite showed losses in weight at 700° and 600° respectively, but no endothermic reactions were detected at these temperatures.

SUMMARY.

Thus, with the exception of cyanite and biotite, all the endothermic reactions detected corresponded with the temperatures at which losses in weight were observed. In a few cases decreases in weight were found without any corresponding endothermic reaction being detected.

Part 9.

FURTHER EXPERIMENTS ON HEATING KAOLIN AND ALUMINA.

It was shown in Part 8 that the temperature at which dehydration began was raised considerably (80° or more) if the materials under examination were heated rapidly instead of very slowly, and that the temperatures at which endothermic reactions were observed with clays and many other substances agreed with the temperatures at which dehydration started when the clays, etc. were heated at the same rate in the two experiments. It seemed possible, therefore, that the changes causing the evolution of heat in clays (at 950°), or in alumina (at 1,060°) prepared by calcining the nitrate at 700°, might be brought about at lower temperatures on heating very slowly. Accordingly, alumina prepared from the nitrate was examined after heating for 24 hours at 900°, 950°, and 1,000° respectively. The exothermic reaction at 1,060° was detected in the specimen previously heated at 900°, but was absent in those which had been heated at 950° and 1,000°. It was evident, therefore, that the change with which this evolution of heat is associated occurred about 950° on slow heating.

Kaolin was heated at 900° for 60 hours and then examined in the differential heating apparatus. The evolution of heat at 950° was considerably less than that found with raw kaolin. 2·8 grms. of raw kaolin and of kaolin burned at 900° were examined separately and the results obtained are shown in Fig. 10. Check experiments gave the following results for the maximum deflection

of the galvanometer due to the change starting at 950°:

Raw kaolin	8·5 ; 8·4
Kaolin after firing at 900° for 60 hrs.	1·9 ; 1·85

It would appear, therefore, that the change which gave rise to the evolution of heat at 950° when kaolin was heated rapidly was brought about at 900° on slow heating. Kaolin which had been heated for 24 hours at 800-850° showed no diminution in the magnitude of the exothermic reaction observed at 950° on taking a differential heating curve.

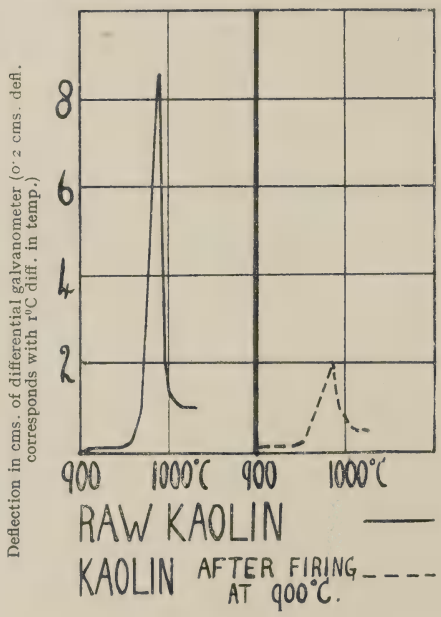

Fig. 10.

It was seen in Part 3 that a red bauxite, which contained practically no silica, showed an exothermic reaction at 1,000°, a temperature 50° higher than that noted for clay. This change cannot be attributed in any way to silica and is most probably due to some change in the alumina. Further, the nature of the heating curve was similar to that given by calcined alumina, the thermal effects being considerably less sharp in both cases than was the evolution of heat observed with clays. The exothermic reaction took place so rapidly with clays that in 2 or 3 minutes the difference in temperature between the specimen and the standard had reached its maximum value (which was considerably greater than the maximum for alumina), but with alumina and red bauxite 8 to 10 minutes were required. Apart from the difference in temperature at which the exothermic reaction took place with clay and

with alumina, the differences in magnitude and character of the changes distinguished them sharply. A consideration of these results leads to the conclusion that the changes in clays at 950° and in alumina at 1,000-1,060° are distinct and different phenomena.

It was seen in the earlier parts of this work that all the clays examined exhibited pronounced shrinkages at about 880° and 950° (see Part 1), on very slow heating, and gave rise to an evolution of heat at 950° on rapid heating. It has now been shown that the change giving rise to this thermal effect took place at 900° on slow heating and was, therefore, due presumably to the same reaction as that producing the shrinkage starting at 880°. The shrinkage at 950° on slow heating occurred at the temperature at which the exothermic reaction observed with alumina prepared from the nitrate took place on slow heating. It would appear possible, therefore, that the shrinkage at 950° is associated with some change taking place at that temperature in the alumina present in the clay.

In part 7 it was shown that the evolution of heat at 950° on heating clays rapidly was not due to the interaction of alumina and silica, or of $Al_2O_3.SiO_2$ and silica, as mixtures of alumina and silica of the composition $Al_2O_3+2SiO_2$, and of andalusite, cyanite, allophane and silica of the composition $Al_2O_3.SiO_2+SiO_2$, showed no exothermic reaction at 950°.

It was possible that the shrinkage observed at 530° might be due to dehydration, or, on the other hand, that dehydration might first take place, and that the shrinkage at 530°C. might then be associated with some further change occurring in the dehydrated material. Accordingly, a test piece was heated in the expansion apparatus for a prolonged period at 450-480° but the rate of dehydration was very slow, due partly to the enclosed nature of the space in which the clay was heated. The specimen was, therefore, heated at 500° in an electric muffle until the loss on ignition was only 1·6%. It was then examined in the expansion apparatus, but no shrinkage was detected at 530°. A second test-piece prepared from raw kaolin was heated slowly in the expansion apparatus, four days being taken to reach 530°. Shrinkage started at this point, and after being maintained at this temperature for 2 hours, the specimen was removed and its loss on ignition was found to be 7·8%, showing that it still contained nearly 62% of its original water content.

It was concluded from these experiments that the shrinkage at 530° was accompanied by the dehydration of the clay, the loss of water taking place at lower temperatures than this being extremely slow in the expansion apparatus owing to the enclosed nature of the space in which the clay was heated.

A piece of kaolin was fired at 480° until its loss on ignition was 4·5%, and was then heated in the differential heating apparatus.

The curve obtained was compared with that given by an equal weight of raw kaolin (loss on ignition 12·4%). It will be seen (see Fig. 11) that the magnitude of the endothermic change shown by the partially dehydrated clay was considerably less than that for raw kaolin. The areas of the curves due to these changes was found to be in the ratio 1 : 2·4 which is in good agreement with that of the water content of the specimens. This result gives added weight to the conclusion drawn from Part 8, that the endothermic reaction at 500° is due to dehydration of the clay. It would appear, therefore, that the shrinkage of the clay observed at 530° and the endothermic reaction starting at 500° are both associated with dehydration.

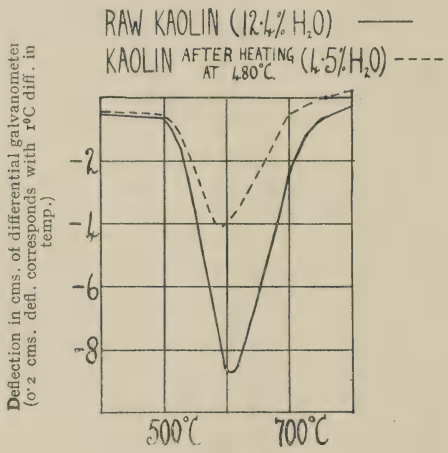

Fig. 11.

SUMMARY.

The results described in Parts 1-9 may be summarised thus :—

1. The shrinkage of clays is not a continuous process, but one which takes place in a number of stages, each stage being completed at a definite temperature. The shrinkages of considerable magnitude occur at almost the same temperatures with the different clays, viz., 530° (except with ball clay), 880°, 950° and 1,030-1,060°. Changes in density and in the refractive index of kaolinite also occur at these temperatures, whilst other observers have noted a decreased solubility of the clay in hydrochloric acid at 900°. Smaller shrinkages occur with kaolin and an aluminous clay (Ayrshire bauxitic) at 620°, 700°, and about 800°.

2. Kaolin and fireclays begin to lose water appreciably on heating slowly at 420-450°. The temperatures of appreciable dehydration of diaspore ($Al_2O_3.H_2O$) [370-400°], gibbsite ($Al_2O_3.3H_2O$) [160-190°], red bauxite [350-410°] and grey bauxite [200-220° and 390-450°], allophane ($Al_2O_3.SiO_2.5H_2O$) [15-90,

120-180, 230-280, and 670-820°] have also been determined. The temperature at which loss in weight is detected is raised considerably (80° or more) if the substances are heated rapidly.

3. The shrinkage of kaolin, etc., observed at 530° is associated with the dehydration of the clay.

4. Kaolin and fireclays show a distinct heat absorption at 500-530° and a heat evolution at 950°. Pure alumina, prepared by calcining the nitrate, gives an exothermic reaction at 1,060° and red bauxite at 1,000°. Heat absorption and evolution are shown by many of the other substances examined. With the exceptions of cyanite and biotite, all the endothermic reactions occur at the same temperatures as those where a loss in weight begins when the materials are heated under similar conditions.

5. The change responsible for the exothermic effects observed at 950° with clays could be completed on continued heating at 900°, and that causing the evolution of heat at 1,060° with alumina could be completed by a similar heating at 900°.

6. None of the indications of exothermic and endothermic reactions with clays can be attributed to the presence of small quantities of impurities and their possible interaction with the clay material.

7. No evolution of heat at 950° was detected when mixtures of alumina and silica of the composition $Al_2O_3+2SiO_2$ were heated, or when mixtures of the composition $Al_2O_3.SiO_2+SiO_2$ prepared from sillimanite, cyanite, andalusite, or allophane and silica were heated.

Many investigators have naturally endeavoured to explain the endothermic effect and the variations in physical and chemical properties observed in clays on heating at about 500° in terms of changes in the chemical constitution of the clay. Thus, as has been mentioned previously, Mellor assumed that kaolin ($Al_2O_3.2SiO_2.2H_2O$) decomposed about this temperature into alumina, silica and water; Knote suggested that two molecules of kaolin decomposed to form one molecule of $Al_2O_3.SiO_2$ and one molecule of $Al_2O_3.3SiO_2$; Samoilov concluded that a special form of allophane ($Al_2O_3.SiO_2$) was formed; and Vernadsky that leverrierite ($Al_2O_3.2SiO_2$) was formed with the liberation of water. Similarly, many theories have been advanced to account for the exothermic reaction occurring at 950° on heating rapidly. Thus Mellor, and Tammann and Pope, from a study of the behaviour of kaolin and alumina on heating, have suggested that the exothermic reaction observed at 950° on rapid heating is due to a change in the alumina set free at 500° (*e.g.*, a change from an amorphous to a crystalline form of alumina), while other investigators have considered the change to be due to a recombination of the $Al_2O_3.SiO_2$ and $Al_2O_3.3SiO_2$ (supposed to be set free at 500°) to form $Al_2O_3.2SiO_2$; or to the possible formation of sillimanite ($Al_2O_3.SiO_2$). Vernadsky has suggested that some changes may be due

to the polymerisation of the leverrierite ($Al_2O_3.2SiO_2$) which he assumed to be formed at 500°.

It would be possible to formulate a theory, based similarly on the chemical changes undergone by the kaolin molecule on heating, in order to interpret the results we have described. However, in the absence of more pronounced analogies than we or others have ever found, in the behaviour of kaolin and that of such other materials as silica, alumina, and aluminium silicates on heating, we do not feel justified in expressing our results in the terms of any such theory. It seems likely that the changes observed on heating clays may be due both to changes in the chemical constitution of the molecules of the clay and to a rearrangement of those groups of molecules which form the unit of crystal structure of the clay. The studies of Sir W. H. Bragg and others have thrown much light in this respect on the constitution of solids, and the results of a preliminary application of these methods to kaolin have been described.* Such changes and rearrangements of the molecules of the clay would presumably be accompanied by such shrinkages, thermal effects, changes in density, refractive index, and solubility in acids, as have been observed in these studies or by other investigators.

* TRANS. **22**, 105-110, 1923.

Il Comportarsi delle Argille, Bauxiti ecc., riscaldando.

di

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Parte 7a.

(*a*) Fenomeni termici osservati nel riscaldare i minerali che possono trovarsi nelle argille.

Fu creduto che alcuni dei più piccoli restringimenti ed altri effetti osservati nel riscaldare le argille (Vedi I.) potessero essere dovuti all' azione reciproca di impurità presenti nelle argille stesse con la sostanza argillosa, od in alcuni casi ai cambiamenti nelle impurità medesime. Tuttavia tali sostanze sono deliberatamente aggiunte nella composizione della ceramica e di altre misture ed hanno il loro proprio scopo al riguardo. Conformemente i fenomeni termali mostrati riscaldando i vari minerali che possono essere presenti nelle argille sia soli o mischiati con un peso uguale di caolino, furono stabiliti dal metodo descritto nella Parte 3a.

RISULTATI OTTENUTI.

(*a*) *Felspati. L'Albite* ($Na_2O.Al_2O_3.6SiO_2$), *l'ortoclasio* ($K_2O.Al_2O_3.6SiO_2$), *l'anortite* ($CaO.Al_2O_32SiO_2$), e *la labradorite* (Ab_2An_3) non mostrarono alcun fenomeno termale nel riscaldarli da soli a 1000°C. e gli unici cambiamenti termali notati nel riscaldare ciascuno di questi minerali misto ad un peso uguale di caolino, furono a 500 e 950°C., cioè ai punti in cui il caolino subì cambiamenti.

(*b*) *Miche* (Vedi Figura 1a.). La *Muscovite* ($K_2O.3Al_2O_3.6SiO_2.2H_2O$) fu riscaldata a 1,100°C., e dette un leggero irreversibile assorbimento di calore ad 810°C. (completato ad 850°C.) dovuto alla deidrazione e ad una possibile decomposizione in *leucite* ed in *sillimanite* ($K_2O.3Al_2O_3.6SiO_2\ 2H_2O\ K_2O.Al_2O_3.4SiO_2+2(Al_2O_3.SiO_2)+2H_2O$)*. Non fu scoperto con questo metodo alcun nuovo fenomeno termale che suggerisse una mutua azione col caolino riscaldando una mescolanza di mica e caolino. La *Biotite* ($K_2O4\ (MgFe)\ O.2\ (Al\ Fe)_2\ O_3.6SiO_2.H_2O$) mostrò una irreversibile reazione endotermica a 950°C., riscaldando a 1,100°C., (completata a 975°C.), dovuta presumibilmente alla decomposizione della biotite per deidrazione, avvenuta a 710°C. (Vedi Parte 8a.). Nessuna mutua azione col caolino fu riscontrata con questo metodo.

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* Doelter (*Neues Jahrb.* **1**, 1, 1897.) trovò la leucite ed il Vernadsky (*Min. Pet. Mitt*, 18, 1898, pag. 26) la sillimanite fra i prodotti della fusione della muscovite.

(*c*) I. *Cloriti*. (Vedi Figura 2). Il *Clorite* (un complicato silicato idrato di alluminio, ferro e magnesio) ha solamente un cambiamento termale riscaldandolo da solo a 1,200°C., cioè un irreversibile assorbimento di calore iniziantesi a 465°C., e completato a 550°C. Nessun fenomeno termale indicatorio di mutua azione col caolino fu osservato riscaldando una mistura di clorite e di caolino (23 $(MgFe)O.7Al_2O_3 13SiO_2.20H_2O$).

Il *perclorite* subì un irrevocabile cambiamento endotermico a 790°C. (completato ad 820°C.), riscaldandolo, dovuto alla deidrazione. Nessun altro cambiamento fu osservato fino a 1,200°C., e nessuna azione reciproca col caolino fu scoperta con questo metodo.

(*d*) *Composti del Ferro* (Vedi Figura 3). La *limonite* ($Fe_2O_3nH_2O$) —riscaldandola, solamente a 1,000°C. mostrò un cambiamento termale, cioè un irreversibile assorbimento di calore a 325°C. (completato a 370°C.) dovuto alla deidrazione. Nessun fenomeno termale fu osservato col caolino. La *Siderite* ($FeCO_3$) dette alcuni risultati molto interessanti—Un grandissimo assorbimento di calore ebbe luogo a 465°C. (completato 563°C.) dovuto alla decomposizione del carbonato. Questa fu seguita da un grande sviluppo di calore a 694°C. (completato a 760°C.) ed un ulteriore effetto esotermico, ma considerevolmente più piccolo a 785°C. (completato ad 820°C.). Nessun altro cambiamento fu osservato riscaldando a 1,200°C. e tutti i cambiamenti furono irrevocabili. Nessun' azione reciproca accompagnata da cambiamenti termali della siderite col caolino fu osservata in questi esperimenti.

(*e*) *Carbonato di Calcio*. Lo Spato islandese ($CaCo_3$) mostrò un irrevocabile assorbimento di calore iniziante a 745°C. (completato a 940°C.) dovuto alla decomposizione del carbonato. Il cambiamento fu lento al principio e divenne dichiarato a 800°C. Nessun altro cambiamento termale fu riscontrato fino a 1,200°C. Nessun fenomeno indicatorio termale di reciproca azione dello spato islandese col caolino, fu osservato riscaldando una mistura delle due sostanze.

(*f*) *Titanio*. Il Rutile (TiO_2) non mostrò alcun cambiamento termale riscaldando a 1,200°C., e nessun fenomeno termale che non fosse caratteristico del solo caolino fu riscontrato nel riscaldare una mistura di rutile e caolino.

(*g*) *Minerali contenenti magnesia*. (Vedi figura 4) La *Serpentina* (poi olivina) 2 $(MgFe)O.SiO_2.H_2O$ provò una reazione endotermica a 585°C. (completata a 670°C.) che corrispose con la deidrazione del minerale (Vedi Parte 8ª.) ed un cambiamento esotermico a 795°C. (completato a 825°C). Nessun altro cambiamento termale fu trovato sino a 1,100°C., e nessun assorbimento o sviluppo di calore non precedentemente trovato con caolino o serpentina soli fu scoperto riscaldando una mistura di parti uguali, di questi minerali.

Talco $3MgO.4SiO_2.H_2O$ dette un piccolo, irrevocabile assorbimento di calore a 985°C. (completato a 1,015°C.) dovuto alla liberazione dell'acqua ed alla possibile decomposizione in enstatite e silice—Così :—

$$3MgO.4SiO_2.H_2O = 3MgO.SiO_2 + SiO_2 + H_2O^*$$

Non mostrò nessun altro cambiamento riscaldando a 1,100°C. e nessun'azione mutua col caolino fu scoperta con questo metodo.

Enstatite ($MgO.SiO_2$) fu studiato come un possibile prodotto di decomposizione della serpentina e talco. Non mostrò alcun fenomeno termale riscaldando a 1,200°C., mentre che una mistura di enstatite e caolino mostrò soltanto i cambamenti termali caratteristici del caolino solo.

L'identità dei risultati ottenuti nel saggiare *separatamente i minerali* ed in mescolanza col caolino rivela un'assenza completa di ogni qualsiasi traccia di azione mutua—I risultati ottenuti per i minerali separati mostrano che le *miche idrate* sono deidrate (o subiscono altra decomposizione) a temperature diverse con assorbimento di calore e così possono esercitare leggeri effetti disturbanti sui fenomeui termali, osservati nelle argille. Ma la natura e l'importanza degli effetti osservati, uniti alla considerazione delle piccole quantità dei minerali normalmente trovate nelle argille, giustificherebbero la conclusione che probabilmente in ogni caso esaminato e riportato nelle parti precedenti di queste pagine, i fenomeni fossero inerenti alle argille e non dovuti alla interposizione delle impurità del minerale presente (altro che per silicati idrati di alluminio.

(B) Ashley† ha suggerito che lo sviluppo di calore osservato vicino ai 980°C. riscaldando un'argilla era dovuto alla possibile formazione della sillimanite dall'allumina e silice liberati dalla decomposizione dell'argilla vicino a 500°C. Per provare questo punto per quanto possibile per mezzo di differenti curve di riscaldamento chiaramente basate, furono preparate intime misture di alluminio e silice della composizione seguente:

$$Al_2O_3 + 2SiO_2.$$

(i.) Precipitato di allumina[2] + cristalli di silice (vitreosil).
Precipitato di allumina[2] + precipitato di silicer (dalla fluorite silicica).
Precipitato di allumina[2] + pura sabbia di quarzo.

(ii.) Allumina[2] (dai nitrati di alluminio) + cristalli di silice (vitreosil).
Allumina[2] (dai ,, ,,) + precipitato silicer (dalla fluorite silicica).
Allumina[2] (,, ,, ,,) + pura sabbia di quarzo.

In nessun caso fu scoperto uno sviluppo di calore nella prossimità di 950°C., di modo che non fu ottenuta alcuna prova da questi esperimenti a sostegno dell'asserzione di Ashley.

Samoilov[3] considerava che una speciale forma di *allofane* ($Al_2O_3SiO_2$) e SiO_2 fosse prodotta dalla decomposizione dell'argilla

* Clarke—*Data of Geo. Chemistry*, pag. 608.
† J. *Ind. Eng. Chem.*, **3**, 91, 1911.
[1] Previamente deidrati a 400° C.
[2] ,, calcinati a 700° C.
[3] *Bull. Acad. Imp. Sci.*, **11**, 779, 1914.

TABELLA I.

Felspati.			
Albite ..	$Na_2O.Al_2O_3.6SiO_2$		
Ortoclasio ..	$K_2O.Al_2O_3 6SiO_2$	Nessun cambiamento termale	
Anortite ..	$CaO.Al_2O_3.2SiO_2$		
Labradorite	Ab_2An_3		
Miche.			
Muscovite ..	$K_2O.3Al_2O_3.6SiO_2$	Assorbimento del calore a 810°C.	Completato a 850°C.
Biotite ..	$K_2O.4(MgFe)O.(2AlFe)_2O_3$	Assorbimento del calore a 950°C.	,, 975°C.
Clorite ..	un complicato silicato idrato di alluminio, ferro e magnesio	Assorbimento del calore a 465°C.	,, 550°C.
Perclorite ..	$23(MgFe)O.7Al_2O_3.13SiO_2.20H_2O$	Assorbimento del calore a 790°C.	,, 820°C.
Limonite ..	$Fe_2O_3.xH_2O$	Assorbimento del calore a 325°C.	,, 370°C.
Siderite ..	$FeCO_3$	Assorbimento del calore a 465°	,, 563°C.
		Svilluppo di calore a 694°	,, 760°C.
		Sviluppo di calore a 785°	,, 820°C.
Spato Islandese ..	$CaCo_3$	Assorbimento di calore 745°	,, 940°C.
Rutile ..	TiO_2	Nessun cambiamento termale	
Serpentina ..	$2(MgFe)O.SiO_2.H_2O$	Assorbimento di calore 585°	,, 670°C.
Talco ..	$3MgO.SiO_2H_2O$	Assorbimento di calore 985°	,, 1015°C
Enstatite ..	$MgO.SiO_2$	Nessun fenomeno termale	

vicino ai 500°C. Perciò lo sviluppo del calore a 950°C. dovrebbe presumibilmente essere dovuto ai cambiamenti in allofane o silice o ad una ricombinazione dei due. Nessun sviluppo di calore fu trovato vicino a 950°C. riscaldando allofane solo (Vedi Parte 3a.) e la silice non mostrò alcun fenomeno termale a questo punto. Per provare questa teoria il più completamente possibile per mezzo di esperimenti termali furono chiaramente preparate varie ed intime misture della composizione $Al_2O_3.SiO_2 + SiO_2$—come segue:

(i.) Sillimanite	($Al_2O_3.SiO_2$)	+ cristalli di silice (vitreosil).
,,	(,,)	+ precipitati silicali (dalla fluorite silicica).
,,	(,,)	+ pura sabbia di quarzo.
(ii.) Cianuro	$Al_2O_3SiO_2$.)	+ cristalli di silice (vitreosil).
,,	(,,)	+ precipitati silicali (dalla fluorite silicica).
,,	(,,)	+ pura sabbia di quarzo.

(iii.)	Andalusite	($Al_2O_3.SiO_2$)	+ cristalli di silice (vitreosil).
,,	(,,)		+ precipitati silicali (dalla fluorite silicica).
,,	(,,)		+ pura sabbia di quarzo.
(iv.)	Allofane[3]	($Al_2O_3SiO_2 5H_2O$)	+ cristalli di silice (vitreosil).
,,	(,,)		+ precipitati silicali (dalla fluorite silicica).
,,	(,,)		+ pura sabbia di quarzo.

Nessuno sviluppo di calore fu trovato con qualunque di queste misture a 950C., cosicché questi esperimenti non dánno alcun appoggio alla teoria di Samoilov.

PARTE 8ª. PERDITA DI PESO PER RAPIDO RISCALDAMENTO. LA RELAZIONE TRA LA PERDITA DI PESO E LE REAZIONI ENDOTERMICHE.

Fu trovato negli esperimenti descritti nelle Parti 2 e 3 (TRANS. 22, 111, 1923) che una differenza di 80°C. o più esisteva fra le temperature in cui le argille, bauxiti, ecc sperimentavano una perdita di peso e quelle in cui furono osservate reazioni endotermiche—Deve ricordarsi tuttavia che le curve differenziali di calore devono essere prese necessariamente ad un certo rapido grado di calore (per i nostri esperimenti fu scelto da 7 ad 8 ° per minuto), mentre che le curve per le perdite di peso furono ottenute riscaldando molto lentamente. Si concepì perciò che le temperature che dettero luogo alle perdite di peso sarebbero aumentate con un rapido riscaldamento ed in conseguenza gli esperimenti della perdita di peso furono ripetuti con la temperatura crescente ad 8°C. per minuto come nelle prove del riscaldamento differenziale—Simili esperimenti furono eseguiti con i minerali usati nella Parte 7ª. I risultati ottenuti sono mostrati graficamente nelle figure 5, 6, 7, 8 e 9. Le temperature alle quals'iniziarono le perdite di peso mediante lento e rapido riscaldamento e quelle alle quali furono osservate le reazioni endotermiche sono riunite nella Tabella II. Si vedrà che le temperature in cui le sostanze esaminate incominciarono a perdere di peso sono state aumentate da 80°C., o più da un rapido riscaldamento e che le *temperature determinate in tale modo concordano benissimo con le temperature in cui si iniziarono le reazioni endotermiche* quando le sostanze furono riscaldate allo stesso grado di calore.

In quasi tutti i casi le reazioni endotermiche osservate furono dovute a cambiamenti, come la deidrazione, o la decomposizione di un carbonato che coinvolge una perdita di peso.

Il Cianuro ($Al_2O_3.SiO_2$) tuttavia ebbe una reazione endotermica a 775°C. che evidentemente non può essere unita ad una diminuzione di peso.

La Biotite diminuì di peso a 710°C., mentre che l'unica reazione endotermica occorse al 950°C.

Si vedrà tuttavia che con queste due inspiegate eccezioni (cianuro e biotite) tutti gli assorbimenti di calore che furono

[3] Previamente riscaldati in fornello a 900°C. per completare la deidrazione.

TABELLA II.

Temperature in cui furono osservate perdite in peso e reazioni endotermiche:—

Sostanza	Formula chimica	Perdita in peso. a lento riscaldamento (°C.)	Perdita in peso. a rapido riscaldamento (°C.)	Reazioni endotermiche
Caolino ..	$Al_2O_3 2SiO_2.2H_2O$	420-450	500	500
Farnley fireclay (argilla resistente al fuoco) ..		425-450	100 480	90 510
Airshire argilla bauxitica		15-90 220 320-390 400-470 (lentamente)	100 320 420 490 (Molto lentamente)	530
Palla d'argilla ..		n.f.	110 480	110 500
Bauxite rossa ..		350-410	90 500	490
Bauxite grigia ..		200-200 390-450	90 310 510	fino a 180 310 510
Gibsite ..	$(Al_2O_3.3H_2O)$	160-190	230	240
Diaspore ..	$(Al_2O_3H_2O)$	370-400	490	470
Allofane ..	$Al_2O_3SiO_2 5H_2O$	120-180 230-280 670-820	110 320* 840	50 (iniziato lentamente) 270 860
Pirofillite ..	$Al_2O_3.4SiO_2.H_2O$	non fatto	490 lentamente 710 (leggermente)	720
Alloisite (?) ..	$Al_2O_3 2SiO_2$ $2H_2OAq.$	non fatto da	15°C. 470	50 490
Silice (precipitato contenente soda)	$SiO_2 + xH_2O +$ soda	non fatto		80
Silice (dalla fluorite silicata) silicata)	$SiO_2.2H_2O$	Soltanto leggerissima perdita di peso previameute riscaldando a 70°C. per lungo periodo		
Allumina (precipitato)	$Al_2O_3.xH_2O$	Dalle temperature di camera con crescita di peso a 110° ed a 220°	90 330*	70 365
Muscovite ..	$K_2O.3Al_2O_3.$ $6SiO_2.2H_2O$	non fatto	820	810
Biotite ..	$K_2O.4(MgFe)O.$ $2(AlFe)_2O_3$ $6SiO_2.H_2O$	non fatto	710	950
Talco ..	$3MgO.4SiO_2.H_2O$	non fatto	950	985
Serpentina ..	$(2MgFe)O.SiO_2$	non fatto	570	585
Limonite ..	$Fe_2O_3.nH_2O$	non fatto	320	325
Siderite ..	$FeCO_3$	non fatto (cominciò molto lentamente a 400	450	465
Clorite ..	Silicato idrato di Al.Fe e Mg.	non fatto (completo a 630)	400 700	390 465
Perclorite ..	$23(MgFe)O.$ $7Al_2O_3$ $13SiO_2.20H_2O$	non fatto	600 820	790
Spato islandese ..	$CaCo_3$	non fatto	700 (lentamente)	745

* Temperatura al cui grado di diminuzione aumentarono in peso.

scoperti corrisposero ad una diminuzione di peso. Il Clorite, un complicato silicato idrato di alluminia, ferro e magnesio mostrò due reazioni endotermiche a 390° ed a 450°C. e cominciò a perdere di peso a 400°C. e ciò continuò fino a 630°C. Non fu possibile di dividere queste diminuzioni di peso, per il rapido riscaldare, in due porzioni. Il Clorite ed il perclorite mostrarono perdite in peso al 700° ed al 600°C. rispettivamente; ma nessuna reazione endotermica fu scoperta a queste temperature.

SOMMARIO.

Perciò con l'eccezione del cianuro e biotite tutte le reazioni endotermiche scoperte corrisposero con le temperature a cui furono osservate le perdite di peso. In pochi casi le diminuzioni di peso furono trovate senza che qualche reazione endotermica corrispondente fosse scoperta.

PARTE 9ª. ULTERIORI ESPERIMENTI RISCALDANDO CAOLINO ED ALLUMINA.

Si mostrò nella Parte 8. che la temperatura in cui cominciò la deidrazione era aumentata considerevolmente (80°C. o più) se le sostanze in esame fossero state riscaldate rapidamente invece di lentamente e che la temperatura in cui furono osservate le reazioni eudotermiche con le argille e molte altre sostanze, concorda con la temperatura in cui cominciò la deidrazione quando le argille furono riscaldate nella stessa misura nei due esperimenti. Sembrò possibile quindi che i cambiamenti causanti lo sviluppo del calore nelle argille (a 950°C.) o nell'allumina (a 1,060°C.) preparati calcinando il nitrato a 700°C. potessero essere portati presso a poco alla più bassa temperatura riscaldando molto lentamente. In conseguenza l'allumina preparata dal nitrato fu esaminata dopo aver riscaldato per 24 ore a 900°C., 950°C., e 1,000° rispettivamente.

La reazione esotermica a 1,060°C. fu scoperta nel pezzo di campione antecedentemente riscaldato a 900°C., ma fu assente in quelli che furono riscaldati a 950° ed a 1,000°C. Fu evidente quindi che il cambiamento col quale questo sviluppo di calore è associato occorse circa a 950° C. riscaldando a lento.

Il caolino fu riscaldato a 900°C. per 6 ore e quindi esaminato negli apparecchi differenziali di riscaldamento. Lo sviluppo di calore a 950°C. fu considerevolmente minore di quello trovato col caolino freddo. 2·8 grammi di caolino freddo e di caolino bruciato a 900°C. furono esaminati separatamente ed i risultati ottenuti sono mostrati nella Figure 10. Gli esperimenti di Clerk dettero i seguenti risultati per la massima deviazione del galvanometro dovuta al cambiamento iniziantesi a 950°C.:—

Caolino freddo	8-5 : 8-4
Caolino dopo essere stato infiammato a 900°C. per 60 ore	1-9 : 1-85

Apparirebbe quindi che il cambiamento che dette origine allo sviluppo di calore a 950°C. quando il caolino fu scaldato rapidamente fosse portato a 900°C. riscaldando leutamente. Il caolino che era stato riscaldato per 24 ore ad 800-850°C., non mostrò alcuna diminuzione nell'importanza della reazione esotermica osservata a 950°C., preudendo una differeuziale curva di calore. Fu visto nella Parte 3a che una bauxite rossa che praticamente non conteneva silice, mostrò-una reazione esotermica a 1,000°C., temperatura di 50°C. più alta di quella notata per l'argilla. Questo cambiamento non può essere attribito in nessun modo alla silice ed è più probabilmente dovuto a qualche cambiamento nell'allumina—Inoltre la natura della curva di riscaldamento era simile a quella data dall' allumina calcinata essendo gli effetti termali considerevolmente meno violenti in entrambi i casi che non fosse lo sviluppo di calore osservato con le argille. La reazione esotermica ebbe luogo così rapidamente con le argille che in due o 3 minuti la differenza di temperatura fra il campione ed il modello regolatore ebbe raggiunto il suo massimo valore (che era considerevolmente più grande del massi mo dell'allumina) ma furono necessari da 8 a 10 minuti con la allumina e la bauxite rossa. Nonostante la differenza in temperatura in cui la reazione esotermica ebbe luogo con l'argilla e con l'allumina, le differenze in grandezza ed il carattere dei cambiamenti, li distinsero nettamente. Una considerazione di questi risultati porta alla conclusione che i cambiamenti nelle argille a 950° e nell'allumina a 1,000-1,006°C. sono distinti e differenti fenomeni.

Fu visto nella prima parte di questo lavoro che tutte le argille esaminate mostravano pronunciati restringimenti a circa 880° e 950°C. (Vedi Parte 1a) riscaldando molto lentamente e davano origine ad uno sviluppo di calore a 950°C. riscaldando rapidamente. E'stato mostrato ora che il cambiamento che dà origine a questo effetto termale, ebbe luogo a 900°C. riscaldando lentamente e fu perciò presumibilmente dovuto alla stessa reazione come il produrre i restringimenti iniziantesi a 880°C. Il restringimento a 950°C. riscaldando a lento avvenne alla temperatura in cui la reazione esotermica (osservata con allumina preparata dal nitrato) ebbe luogo riscaldando a lento. Sembrerebbe quindi possibile che il restringimento a 950° è associato a qualche cambiamento avente luogo a quella temperatura, nell' allumina presente nella argilla.

Nella Parte 7a fu mostrato che lo svilippo di calore a 950°C. riscaldando rapidamente le argille non fosse dovuta alla mutua azione dell'allumina e della silice o di $Al_2O_3SiO_2$ e silice, poichè le misture di allumina e silice della composizione $Al_2O_3+2SiO_2$, e di andalusite, cianuro, allofane e silice della composizione $Al_2O_3-SiO_2+SiO_2$ non mostravano nessuna reazione esotermica a 950°C. Era possibile che i restringimenti osservati a 530°C. potessero essere dovuti alla deidrazione o d'altra

parte che la deidrazione potesse aver luogo prima e che i restringimenti a 530°C. potessero essere collegati con qualche ulteriore cambiamento occorrente nella sostanza deidrata. In conseguenza un pezzo di prova fu riscaldato nell'apparecchio di espansione per un periodo continuato da 450 . a 480°C.; ma la proporzione di deidrazione fu molto lenta dovuta in parte alla natura chiusa del luogo in cui fu riscaldata l'argilla. Il pezzo fu allora riscaldato a 500° in una muffola elettrica fino a che la perdita per ignizione fu soltanto dell' 1·6%. Fu allora esaminato nell'apparecchio di espansione ma nessun restringimento fu scoperto a 530°C. Un secondo pezzo di prova preparato dal caolino freddo fu riscaldato lentamente nell'apparecchio di espansione; furono necessari 4 giorni per raggiungere 530°C. Incominciati a questo punto i restringimenti e dopo aver mantenuto questa temperatura per due ore, il campione fu rimosso e la sua perdita di ignizione fu trovata essere del 7.8% mostrando che ancora manteneva circa il 6% del suo contenuto originale di acqua. Fu concluso da questi esperimenti che il restringimento a 530° fu accompagnato dalla deidrazione dell'argilla, la perdita dell'acqua avendo luogo a più bassa temperatura di questa estremamente lenta nello apparato di espansione dovuta alla chiusa natura del luogo in cui l'argilla fu riscaldata.

Un pezzo di caolino fu infiammato a 480°C., fino a che la sua perdita d'ignizione fu del 4· 5% e fu quindi riscaldato nell' apparecchio differenziale di riscaldamento. La curva ottenuta fu paragonata con quella data da un ugual peso di caolino freddo (perdita di ignizione del 12.4%) Si vedrà (Vedi fig. 11) che l' importanza del cambiamento endotermico mostrato dall'argilla parzialmente deidrata fu considerevolmente minore di quella per il caolino freddo. Le superfici delle curve a questi cambiamenti si trovò che erano in ragione dell' 1:2.4 il che ben concorda con quello dell' acqua contenuta nei campioni. Questo risultato rinforza la conclusione dedotta dalla Parte 8 che la reazione endotermica a 500°C. è dovuta alla deidrazione dell'argilla. Sembrerebbe quindi che il restringimento dell'argilla osservato a 530°C. e la reazione endotermica iniziantesi a 500°C. siano entrambi associati con deidrazione.

SOMMARIO.

I risultati descritti nelle Parti 1-9 possono essere compendiati così:

I. Il restringimento delle argille non è un processo continuo; ma un processo che ha luogo in un numero di stadi, ciascun stadio essendo completato da una temperatura definita. I restringimenti di una considerevole grandezza hanno luogo quasi alla stessa temperatura con le differenti argille, cioè 530° (eccezion fatta con palla d'argilla). 880°C., 950°C. e da 1,030 a 1,06°C. I cambiamenti in densità e nell'indice refrattivo del caolinite avvengono anche a queste temperature, mentre che altri osservatori

(studiosi) hanno notato una solubilità decrescente dell'argilla nell' acido idroclorito a 900°C. Più piccoli restringimenti avvengono col caolino ed un argilla alluminosa (Airshire bauxitico) al 620°C., 700°C. e circa all' 800°C.

II°. Il caolino e le argille infiammate cominciano a perdere acqua notevolmente riscaldando lentamente da 420 a 450°C. Le temperature di valutabile deidrazione del diaspore ($Al_2O_3H_2O$) (370-400°C.), gibsite ($Al_2O_3.3H_2O$) (da 160 a 190°C.), la bauxite rossa (da 350° a 410°C.) e la grigia bauxite (da 200 a 220°C. e da 390 a 450°C.) l'allofane ($Al_2O_3.SiO_2.5H_2O$) da 15-90 . 120-180-230-280 e da 670-820 sono state anche determinate. La temperatura a cui la perdita di peso è manifesta è aumentata considerevolmente (80°C. o più) se le sostanze sono riscaldate rapidamente.

III°. Il restringimento del caolino ecc, osservato a 530°C. è associa to con la deidrazione dell'argilla.

IV°. Il caolino e le argille infiammate mostrano un distinto assorbimento di calore da 500 a 530°C. ed ed uno sviluppo di calore a 950°C. L'allumina pura, preparata calcinando il nitrato, dà una reazione esotermica a 1,060°C. e la bauxite rossa a 1,000°C. L 'assorbimento e lo sviluppo di calore sono mostrati da molte altre sostanze esaminate. Eccezion fatta del cianuro e biotite, tutte le reazioni endotermiche si manifestano alle stesse temperature di quelle in cui cominciano le perdite di peso se le sostanze sono riscaldate alle stesse condizioni.

V°. Il corrispondente cambiamento per gli effetti esotermici osservati a 950°C.con argille potrebbe essere conpletato continuando il riscaldamento a 900°C. e quello causante lo sviluppo di calore a 1,060°C. con allumina protrebbe essere conpletato da un simile riscaldamento a 900°C.

VI°. Nessun indicazione di reazioni esotermiche ed endotermiche con argille pùo essere attribuita alla presenza di piccole quantità di impurità e dalla possibile loro mutua azione col materiale argilloso.

VII°. Nessuno sviluppo di calore a 950°C. fu scoperto quando furono riscaldate le misture di allumina e silice della composizione $Al_2O_3+2SiO_2$, o quando le mixture della composizione $Al_2O_3.SiO_2+SiO_2$pr eparate dalla sillimanite, cianuro, andalusite od allofane e silice, furono riscaldate.

Molti sperimentatori hanno naturalmente tentato di chiarire l'effetto endotermico e le variazioni nelle proprietà fisiche e chimiche osservate nelle argille riscaldando a circa 500°C. nei limiti dei cambiamenti della composizione chimica dell'argilla. Così, il Mellor ammise che il caolino ($Al_2O_3.2SiO_2.2H_2O$) (come abbiamo menzionato prima), si decompose circa a questa temperatura in allumina, silice ed acqua; *Knote* suggeri che due molecole di caolino si decomposero per formare una molecola di $Al_2O_3.Sio_2$ ed una molecola di $Al_2O_3.3SiO_2$; *Samoilov* concluse che una forma speciale di allofane ($Al_2O_3.SiO_2$) si formò: e *Vernadsky* che la

leverrierite ($Al_2O_3.2SiO_2$) fu formata dalla liberazione della acqua. Similmente molte teorie sono state addotte riguardo le reazioni esotermiche manifestantesi a 950°C. riscaldando rapidamente. Cosi, il *Mellor*, il *Tamman* ed il *Pope* da uno studio sulla condotta del caolino ed allumina riscaldati, hanno suggerito che la reazione esotermica osservata a 950°C. a rapido riscaldamento è dovuta ad un combiamento in allumina resa libera a 500°C. (cio è un cambiamento da una forma amorfa ad una forma cristallina di allumina), mentre altri sperimentatori hanno considerato il cambiamento essere dovuto alla ricombinazione del $Al_2O_3.SiO_2$ ed $Al_2O_3.3SiO_2$ (supposta di esser resa libera a 500°C.) per formare $Al_2O_3.2SiO_2$; o dalla possibile formazione della sillimanite)Al_2O_3. SiO_2). Il Vernadsky ha suggerito che certi cambiamenti possono essere dovuti alla polimerizzazione della leverrierite ($Al_2O_3.2SiO_2$) che egli asserisce essere formata a 500°C. Sarebbe possibile formulare una teoria parimenti basata sui cambiamenti chimici subiti dalla molecola del caolino riscaldandolo, per interpretare i risultati che abbiamo descritti. Tuttavia in mancanza di più pronunciate analogie che noi od altri abbiamo sempre trovato nel comportarsi del caolino e nella condotta di certe altre sostauze, quali la silice l'allumina ed i silicati d' ammonio riscaldati, non ci sentiamo giustificati nell'esprimere i nostri risultati nei termini di una qualsiasi teoria. Sembra probabile che i cambiàmenti osservati nel riscaldare le argille debbano essere dovuti ai cambiamenti nella costituzione chimica delle molecole dell'argilla e ad una ridisposizione di quei gruppi di molecole che formano l'unità della struttura del cristallo dell'argilla. Gli studi di Sir W. H. Bragg e di altri hanno gettato molta luce a questo riguardo sulla costituzione dei solidi; ed i risultati di una applicazione preliminare al caolino, di questi metodi, sono stati descritti*. Tali cambiamenti e riassettamenti delle molecole del l'argilla sarebbero accompagnati da restringimenti, effetti termali, cambiamenti in densità, indici rifrattivi e solubilità in acidi, come abbiamo osservato in questi studi o col mezzo di altri sperimentatori.

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*TRANS., **22**, 105—110. 1923

XXIV.—The Influence of Phosphoric Acid and Phosphates on the Rate of Inversion of Quartz in Silica Brick Manufacture.*

W. Hugill, B.Met. and W. J. Rees, B.Sc., F.I.C.

In a paper by O. Rebuffat (Trans., **21**, 66, 1922) the results of experiments are recorded, indicating that the presence of (or addition of) phosphoric oxide in certain Italian quartzites considerably increased the rate of inversion of the quartz. In order to ascertain if the same effect was produced by the addition of phosphoric oxide or phosphates to British quartzites, the following experiments have been made:—Briquettes $4'' \times 1\frac{1}{2}'' \times \frac{3}{4}''$ were made from Totley ganister, Bwlchgwyn quartzite and Llangefni quartzite, the grading of the briquettes being:—

Through	5 mesh and on	10 mesh sieve	20%	by weight
,,	10 ,, ,,	20 ,, ,, ...	17	,,
,,	20 ,, ,,	30 ,, ,, ...	5	,,
,,	30 ,, ,,	90 ,, ,, ...	15	,,
,,	90 mesh	.. ..	43	,,

The chemical analyses of these quartzites gave the following percentage results:—

	Totley	Bwlchgwgn	Llangefni
Silica	97·54	97·35	97·37
Alumina	0·78	1·09	1·31
Iron Oxide..	0·52	0·58	0·38
Titanic Oxide	0·22	0·13	0·09
Lime	0·14	0·09	0·02
Magnesia	0·11	0·11	0·18
Alkalies (as K_2O)	0·39	0·37	0·41
Loss on ignition	0·21	0·34	0·38
	99·91	100·06	100·14
P_2O_5	0·011%	0·014%	0·003%

The following series of briquettes was made:—

Series A.

1. Totley ganister with 2 per cent. of CaO
2. ,, ,, ,, 2 ,, CaO and 0·5 per cent. phosphoric oxide
3. ,, ,, ,, 1 per cent. CaO and 2·5 per cent. basic slag.
4. ,, ,, ,, 5 per cent. of basic slag.

Series B, 1, 2, 3, and 4. The above mixtures were repeated, substituting Bwlchgwyn quartzite for Totley ganister.

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Series C, 1, 2, 3, and 4. As Series *A* and *B*, but with Llangefni quartzite as raw material.

Pure phosphoric oxide was used and the approximate analysis of the basic slag used was :—

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	P_2O_5	MnO
21·6	3·2	14·7	38·6	2·4	11·8	7·6%

The briquettes were placed together in a silica brick kiln and burned to cone 16. Those containing basic slag were, after burning, much browner in colour than the others. The true specific gravity (powder density) of the briquettes after burning was as follows :—

	Series *A*	Series *B*	Series *C*
1	2·45	2·48	2·46
2	2·43	2·45	2·45
3	2·42	2·45	2·42
4	2·42	2·42	2·40

These results suggest that, with the particular raw quartzites used in the experiments, the rate of quartz conversion is only very slightly increased by the presence of phosphoric oxide. It is quite likely that the greater degree of quartz conversion in briquettes 3 and 4 of all three series is due to the iron oxide in the basic slag added (see Scott, TRANS. **18**, 481, 1919).

A series of bricks, $9'' \times 4\frac{1}{2}'' \times 3''$, was also made from Totley ganister and Bwlchgwyn quartzite with the ordinary commercial grading.

Series *D*. Totley ganister with 1·5 per cent. CaO and 0·5 per cent. P_2O_5
Series *E*. ,, ,, ,, 4 per cent. basic slag.
Series *F*. Bwlchgwyn quartzite ,, 1·5 per cent. CaO and 0·5 per cent. P_2O_5
Series *G*. ,, ,, ,, 4 per cent. basic slag.

These bricks were placed together in the kiln and burned at cone 18. The powder density of these bricks and of normal bonded bricks (1·5 per cent. CaO), from the same portion of the kiln was as follows :

Normal brick Totley ganister	Series *D*	Series *E*	Normal brick Bwlchgwyn Stone	Series *F*	Series *G*
2·42	2·41	2·41	2·43	2·41	2·43

The bricks containing basic slag were again much browner than the normal bonded bricks. These results are in agreement with those obtained with the small briquettes and indicate that, with the raw materials used, there is no advantage in the addition of phosphoric oxide to the normal silica brick batch.

Through the courtesy of Mr. W. J. Gardner, of the Meltham Silica Firebrick Co. Ltd., batches of bricks were made in which (*a*) 1 per cent. of lime and 2 per cent. of basic slag and (*b*) 4 per cent. of basic slag were added to the Meltham mixture of raw

materials of the normal grading. These bricks were burned at cone 18. The true specific gravities were as follows: Normal Meltham bricks 2·25; bricks with 1 per cent. lime and 2 per cent. basic slag 2·36; bricks with 4 per cent. basic slag 2·38. With this raw material it is evident that the addition of phosphoric oxide has no favourable effect on the rate of quartz conversion. The writers have also been informed by Mr. J. Holland, that trials with phosphoric oxide and with basic slag additions have been made at both the Sheffield and Crook Works of Pickford, Holland & Co. Ltd., and that in each case a negative result was obtained.

Incidentally the *effect of molybdic oxide* was tried and a few bricks were made of Totley ganister bonded with 5 per cent. of ball clay with the addition of 0·2 per cent. of ammonium molybdate in solution. The bricks were burned at cone 16. The powder density of the bricks was 2·46 and was identical with that of a similar batch of bricks without the molybdate addition, but the subject was not followed further because of possible loss of molybdate by volatilisation.

L'Influenza dell'Acido Fosforico e dei Fosfati sul Grado d'Inversione del Quarzo nella Fabbricazione dei Mattoni Silicei.*

W. Hugill, Baccelliere in Metallografia e
W. J. Rees, Baccelliere in Scienze, F.I.C.

In una memoria di O. Rebuffat (Trans., **21**, pag. 66, 1922) sono sintetizzati i risultati di esperimenti che mostrano chè la presenza (o l'aumento) di ossido fosforico in alcune quarzite italiane aumentò considerevolmente il grado d'inversione del quarzo. A fine di accertare sè si otteneva lo stesso effetto coll'aggiunta di ossido fosforico o di fosfati alle quarzite brittanniche, si fecero i seguenti esperimenti: Si fecero dei mattoni di 102 × 38 × 19 mm. composti di ganistro di Totley, quarzite di Bwlchgwyn e quarzite di Llangefni, aventi le seguenti gradazioni:

Attraverso staccio di 5 e su staccio di 10 maglie : 20% per peso.
,, ,, 10 ,, ...20 : 17% per peso
,, ,, 20 ,, 30 : 5% ,,
,, ,, 30 ,, 90 : 15% ,,
,, ,, 90 .. .. 43% ,,

Le analisi chimiche di queste quarzite hanno dato i seguenti risultati.

	Totley	Bwlchgwyn	Llanyefni
Silice	97·54	97·35	97·37
Allumina	0·78	1·09	1·31
Ossido di ferro	0·52	0·58	0·38
Ossido di titanio	0·22	0·13	0·09
Calce	0·14	0·09	0·02
Magnesia	0·11	0·11	0·19
Alcali (come K_2O)	0·39	0·37	0·41
Perdita per ignizione	0·21	0·34	0·38
	99·91	100·06	100·14
P_2O_5	0·011%	0·014%	0·003%

Le seguenti serie di mattoni furono fatte:

Serie A.

1. Ganistro Totley con 2% di CaO
2. ,, ,, ,, 2% di CaO e 0·5% di ossido fosforico
3. ,, ,, ,, 1% di CaO e 2·5% di scoria basica
4. ,, ,, ,, 5% di scoria basica.

*Stampato col permesso del consiglio della British Refractories Research Association.

Serie B. 1, 2, 3 e 4. Furono ripetute le suddette miscele sostituendo quarzite Bwlchgwyn in luogo di ganistro Totley.
Serie C. 1, 2, 3 e 4. Come le serie *A* e *B* ma con quarzite Llangefni come materia prima.

Si usò ossido fosforico puro e l'analisi approssimata della scoria basica usata fu la seguente :

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	P_2O_5	MnO
21·6	3·2	14·7	38·6	2·4	11·8	7·6%

I mattoni furono posti insieme in una fornace da laterizi silicei e bruciati fino al cono 16. Quelli contenenti scoria basica erano, dopo la cottura, molto più scuri degli altri. Il peso specifico vero (densità di polvere) dei mattoni dopo la cottura era il seguente :

	Serie *A*	Serie *B*	Serie *C*
1	2·45	2·48	2·46
2	2·43	2·45	2·45
3	2·42	2·45	2·42
4	2·42	2·42	2·40

Questi risultati suggeriscono che colle speciali quarzite grezze usate nelle esperienze il grado di conversione del quarzo è solo leggermente aumentato dalla presenza di ossido fosforico. E ben probabile che il maggior grado di conversione del quarzo nei mattoni 3 e 4 di tutte queste tre serie sia dovuto all'ossido di ferro della scoria basica aggiunta (Vedere Scott, TRANS., xviii., pag. 481).

Una serie di mattoni di 229×114×76 mm. fu anche fabbricata con ganistro di Totley e quarzite di Bwlchgwyn aventi l'ordinaria graduazione commerciale.

Serie *D.*	Ganistro Totley	con	1·5% di CaO e 0·5% di P_2O_5
Serie *E.*	,, ,,	,,	4% di scoria basica.
Serie *F.*	Quarzite Bwlchgwyn	,,	1·5% di CaO e 0·5% di P_2O_5
Serie *G.*	,, ,,	,,	4% di scoria basica.

Questi mattoni furono posti insieme in un forno e bruciati a cono 18. La densità di polvere di questi mattoni e di mattoni normali cementati (con 1·5% di CaO) dalla stessa zona della fornace era come segue :

Mattone normale Ganistro di Totley	Serie *D*	Serie *E*	Mattone normale Pietra di Bwlchgwyn	Serie *F*	Serie *G*
2·42	2·41	2·41	2·43	2·41	2·43

I mattoni contenenti scoria basica erano di nuovo molto più scuri che dei mattoni normali cementati. Questi risultati sono d'accordo con quelli ottenuti coi mattoni piccoli e mostrano chè con le materie prime usate non v'è vantaggio ad aggiungere ossido fosforico alla cotta normale di mattoni silicei.

Grazie alla cortesia del Sig. W. J. Gardner, della Ditta Meltham Silica Firebrick Co. Ltd., furono fatte delle cotte di mattoni nelle quali alla miscela Meltham di materie prime di gradazioni normali si aggiunsero :

(*a*) 1 per cento di calce e 2 per cento di scoria basica e
(*b*) 4 per cento di scoria basica.

Questi mattoni furono cotti al cono 18. I pesi specificf veri erano i seguenti : Mattoni Meltham normali : 2·25—Mattoni con 1 per cento di calce e 2 per cento di scoria basica : 2·36—Mattoni con 4 per cento di scoria basica : 2·38. Con questa materia prima è evidente chè l'aggiunta di ossido fosforico non ha un effetto favorevole sul grado di conversione del quarzo. Gli autori sono stati anche informati dal Sig. J. Holland chè si sono eseguite delle prove con aggiunte di ossido fosforico e di scoria basica nelle due fabbriche di Sheffield e di Crook della Ditta Pickford, Holland & Co. Ltd., e chè si è ottenuto sempre risultato negativo.

Incidentalmente si esperimentò l'uso dell 'ossido molibdenico e si fabbricarono pochi mattoni di ganistro di Totley cementati con 5 per cento di argilla a palla con l'aggiunta di 0·2 per cento di molibdato ammonico in soluzione. I mattoni furono cotti al cono 16. La densità di polvere dei mattoni era di 2·46 ed era identica a quella di una cotta simile de mattoni senza aggiunta di molibdato, ma non si continuò a trattare il soggetto a causa della possibile perdità di molibdato per volatilizzazione.

XXV.—Sintesi e Fabbricazione Industriale della Sillimanite.

di O. Rebuffat.

La Sillimanite ($SiO_2.Al_2O_3$) è entrata nel campo degli studi ceramici nel 1907-1908, cio è quando prima Plenske e poi Zoellner[1] ne constatarono la presenza nella porcellana dura.

Posteriormente vennero messe in rilievo le più eminenti qualità di questo composto, cio è l'alto punto di fusione e la stabilità del volume nel prolungato riscaldamento ad elevate temperature e si pose cosi naturalmente il problema della introduzione della sillimanite nella fabbricazione dei refrattari ; problema pel quale non era stata sinora trovata una soluzione soddisfacen·e.

Tale problema è inrealtà duplice, perchè concerne non solo la produzione ma benanco il tecnicismo dell'impiego della sillimanite ; essendo questa sostanza priva di plasticità.

La produzione artificiale della sillimanite si impone, data la deficienza di importanti giacimenti della stessa e l'abbondanza delle materie prime che possono impiegarsi per fabbricarla.

Però la sintesi diretta da $SiO_2+Al_2O_3$ avviene solo a temperatura elevatissima e nella forma industriale datele recentemente non permette di ottenere un prodotto di conveniente purezza[2].

Del resto anche riuscendo a fabbricare la sillimanite da $SiO_2+Al_2O_3$ in condizioni tecnicamente ed economicamente convenienti non si è risoluto il problema del suo impiego nella fabbricazione dei refrattari : perchè il prodotto avrà sempre bisogno di un agglomerante plastico e questo porterà di conseguenza all'abbassamento del punto di fusione ed alla instabilità del volume.

Allorchè ho cominciato ad occuparmi di un tale problema ho fatto qualche tentativo di sintesi diretta per mezzo dello idrato silicico e dell'idrato di allumina, nella speranza di portare i due ossidi in combinazione prima che per la perdita dell'acqua di idratazione passassero in forme di condensazione inerti a bassa temperatura : ma anche dopo lungo ed intimo contatto dei due idrati, con diverse modalità, il miscuglio cotto a 1,400° non presentava alcuno dei caretteri della sillimanite.

Più opportunamente mi decisi allora di utilizzare il particolare stato di attività chimica che presenta la caolinite disidratata a non oltre 700°.

Allorquando, parecchi anni or sono, mi occupavo della costituzione dei cementi idraulici potei di mostrare come la perdita delle due molecole di acqua di idratazione renda la caolinite atta ad entrare facilmente in combinazione con la calce e con altre basi e potei cosi dar ragione della formazione dei cementi a presa rapida e della costituzione delle pozzolane artificiali[3].

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[1]—Plenske—*Ueber Mikrostruktur und Bildung der Porzellane.*—Dissertation, Aachen 1907; Zoellner—Dissertation—Berlin, 1908.

[2]—Malinovsky—*J. Am. Cer. Soc.* **3**, 40, 1920.

Secondo l'a la formazione della sillimanite e preceduta dalla formazione di carburi metallici. Nel prodotto della reazione i cristalli di sillimanite sono impastati con vetro e scoria.

[3]—O. Rebuffat. *Gazz. Chim Ital.* **32**, part II, 1902; **30**, p. II. 1900.

Queste mie esperienze, sinora quasi del tutto ignorate nel campo ceramico, sono in contraddizione con la diffusa opinione che nella disidratazione della caolinite si abbia scissione completa in $2SiO_2 + Al_2O_3$; ma questo modo di vedere non riposa che sulla interpretazione di alcuni fenomeni fisici, per i quali si possono trovare facilmente altre spiegazioni, mentre le mie esperienze hanno condotto alla formazione di composti chimici di costituzione determinata e non ammettono una diversa interpretazione[4].

E che la mia interpretazione della costituzione della caolinite disidratata sia esatta è dimostrato dal successo delle mie esperienze.

Ho detto di sopra come non si riesca ad avere la sillimanite facendo reagire per molto tempo ad umido l'idrato silicico con l'idrato di allumina e poi cuocendo il miscuglio a 1,400°. Se invece si fa reagire l'idrato di allumina sulla caolinite mescolando prima intimamente ad umido e poi riscaldando gradatamente sino a 1,400°, la sillimanite si forma integralmente[5].

Il prodotto ottenuto con tale procedimento presenta infatti, oltre la voluta composizione percentuale, le più caratteristiche proprietà della sillimanite e cio è la indifferenza verso l'acido fluoridrico, l'alta refrattarietà e la stabilità del volume.

Al microscopio il prodotto si dimostra formato da un miscuglio di sillimanite cristallina e sillimanite amorfa. La proporzione di questa ultima va decrescendo rapidamente col prolungarsi del riscaldamento a 1,400° e a temperature superiori.

Il procedimento sopra descritto non solo permette di avere facilmente della sillimanite in istato di grande purezza, ma, cosa più importante, permette ancora di avere una massa plastica di dosaggio rigorosamente sillimanitico; la quale con la cottura si trasforma integralmente in sillimanite.

Infatti mescolando intimamente ad umido la caolinite con l'idrato di allumina oppure il caolino, od un'argilla ricca in caolinite od altro silicato di allumina idrato, con l'idrato di allumina o con la bauxite si ottengono delle masse plastiche adatte alla lovorazione ceramica. Queste masse presentano (come tutti i materiali troppo alluminosi) una contrazione alla cottura superiore alla normale, che viene facilmente corretta con l'aggiunta del biscotto di uguale composizione.

Laboratorio di chimica Tecnologica della R. Scuola Superiore Politecnica di Napoli.

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(4)—La caolinite disidratata a 600-700° si combina alla temperatura ordinaria con l'idrato di calcio dando un composto $2SiO_2.Al_2O_3.3CaO.10H_2O$, che decomposto con gli acidi dà un silicato di alluminio idrato $2SiO_2.Al_2O_3.4H_2O$. (O. Rebuffat-*Le pozzolane artificiali*).

Vedi anche le richerche posteriori di Pukall (B. 43 p. 2078, 1910) sull'acido alluminosilicico.

(5)—Il dott. Bleininger del Bureau of Standards nelle sur ricerche sui diversi tipi di porcellana (*J. Amer. Cer. Soc.* **1**, 623, 1918,) espone di aver preparato una *calcina sillimanitica* cuocenda al cono 20 un intimo miscuglio di 250 p. di Caolino del Nord Carolina, 102 p. di allumina *anidra* e 7, 2 parti di *acido borico*. Il miscuglio di caolino ed allumina era ottenuto *a secco*. Il prodotto della cottura mostrava al microscopio rarissimi aghetti cristallini. Il modo come è fatto il miscuglio, l'impiego dell'allumina anidra e quello dell'acido borico differenziano nettamente le ricerche del dott. Bleininger dalle mie. Il dott. Bleininger non ha del resto menomamente intravvista la possibilità di avere una massa plastica a composizione sillimanitica.

Synthesis and Industrial Manufacture of Sillimanite.

By O. Rebuffat.

SILLIMANITE ($SiO_2Al_2O_3$) first became an object of study in ceramics in 1907-8, when Plenske and later Zöllner[1] described its presence in hard porcelain. Later on, the more important properties of this compound came under notice, especially the high softening point and the volume stability under prolonged heating at high temperatures ; thence followed the problem of the introduction of sillimanite into the manufacture of refractories, a problem to which a satisfactory solution has not yet been found. The nature of this problem is really duplex, since it concerns not only the production of sillimanite, but also the technique of its use, it being a substance devoid of plasticity. We have to consider the artificial production of sillimanite on account of the lack of important deposits of this compound and also on account of the abundance of raw material which can be so used by the manufacturer.

Direct synthesis from silica and alumina can only occur at very high temperatures and the industrial forms which have recently been described do not allow a product of sufficient purity to be obtained[2]. On the other hand, even if the manufacture of sillimanite from silica and alumina could be successfully undertaken under suitable conditions, both technical and economic, this would not solve the problem of its use in the manufacture of refractories, since the product always requires a plastic bond and this will consequently involve a lowering of the softening point as well as volume changes.

When I began to investigate this problem, I made some experiments on direct synthesis by means of hydrated silica and hydrated alumina, in the hope of bringing the two oxides into combination before they passed, with the loss of the water of hydration, into the form of an inert compound at low temperatures. Nevertheless, even with intimate contact of the two hydrates in varying proportions, the mixture heated to 1,400° did not show any of the characteristics of sillimanite. I then decided to utilise the particular state of chemical activity exhibited by kaolinite dehydrated below 700°.

For a few years I was concerned with the examination of the constitution of hydraulic cements, and I then showed how the

(1) Plenske—*Ueber Mikrostruktur und Bildung der Porzellane.*—Dissertation, Aachen 1907; Zoellner—Dissertation—Berlin, 1908.

(2) Malinovsky—*J. Amer. Cer. Soc.*, **3**, 40, 1920. According to this writer, the formation of sillimanite is preceded by the formation of metallic carbides in the product of this reaction. The crystals of sillimanite are interspersed with glass and slag.

loss of two molecules of the water of hydration made kaolinite enter readily into combination with lime and with other bases as it does in the formation of rapid setting cements and artificial pozzolanas[3]. My experiments, still practically unknown in ceramics, contradict the general opinion that in the dehydration of kaolinite there is a complete splitting up into free silica and free alumina; this view rests only on the interpretation of certain physical phenomena for which another explanation can easily be found; my experiments have led to the formation of chemical compounds of definite constitution and do not admit of other interpretation[4].

My interpretation of the constitution of dehydrated kaolinite may be said to have been demonstrated by the success of my experiments. I have shown above how it is not possible to make sillimanite by the reaction at high temperatures of mixtures (dry) of hydrated silica and alumina and then firing the mixture to 1,400°. Nevertheless, if hydrated alumina be very intimately mixed by a wet method with kaolinite and then gradually heated to 1,400°, sillimanite is definitely formed[5]. The product obtained by this method shows, besides the percentage composition of sillimanite, the most characteristic properties of this mineral, namely, its indifference to hydrofluoric acid, its high refractoriness and its stability of volume. Under the microscope the product is seen to be composed of crystalline sillimanite and amorphous sillimanite, the proportion of the latter decreasing rapidly with a prolongation of the heating at 1,400° or when heated to higher temperatures.

The procedure described above not only allows of the easy production of sillimanite in a state of great purity, but what is much more important, gives a plastic mass of exact sillimanitic composition; this is transformed wholly into sillimanite on heating. Indeed the ultimate mixing, by a wet method, of kaolinite with hydrated alumina, china clay, or a clay rich in kaolinite or other hydrated silica, alumina or bauxite, gives a plastic mass very suitable for working in ceramic processes. This material shows, as do all highly aluminous materials, a firing contraction which is much greater than the normal, but which can be easily corrected by the use of grog of the usual composition.

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(3) O. Rebuffat—*Gazz. Chim. Ital.*, **32**, part II., 1902. O. Rebuffat—*Gazz. Chim. Ital.*, **30**, 1900, p. II.

(4) Kaolinite dehydrated at 600-700° combines at ordinary temperatures with hydrate of lime to give the compound $2SiO_2.Al_2O_3.3CaO.10H_2O$ which, decomposed with acids, gives a hydrated aluminosilicate, $2SiO_2.Al_2O_3.4H_2O$. (O. Rebuffat, *Le pozzolane artificial*). See also the later work of Pukall on alumina. (*B.* **43**, p. 2078, 1910).

(5) Bleininger of the Bureau of Standards in his researches on different types of porcelain (*J. Amer. Cer. Soc.*, **1**, 623. 1918.) claims to have prepared a sillimanitic mortar which at Cone 20 forms an intimate mixture of 250 parts of North Carolina kaolin and 150 parts of anhydrous alumina and 7·2 parts of boric acid. The kaolin and the alumina were mixed in the dry condition. This mixture when fired showed under the microscope crystalline needles. Not only did the experiments of Bleininger differ from mine in the matter of the mixing, but also in the use of anhydrous alumina and boric acid. Bleininger has apparently not so far examined the possibility of preparing a plastic mass of the composition of sillimanite.

XXVI.—Results of an X-Ray Investigation of the Crystalline Nature of China Clays, Etc.

By G. Shearer, M.A., Ph.D.

(1) *Substances Examined.*

The following substances were examined by the X-ray spectrometer:—

(*a*) China clay heated at 1,200°
(*b*) China clay heated at 1,700°
(*c*) China clay (1 mol.) + alumina (1 mol.) heated at 1,200°
(*d*) China clay (1 mol.) + alumina (1 mol.) ,, 1,700°
(*e*) China clay (1 mol.) + alumina (2 mols.) ,, 1,200°
(*f*) China clay (1 mol.) + alumina (2 mols.) ,, 1,700°
(*g*) Alumina heated at 1,200°
(*h*) Alumina heated at 1,700°
(*i*) Sillimanite (natural).

The last three were examined in order to see whether or not free alumina or free sillimanite existed in the china clays.

(2) *Experimental Method.*

All the substances were examined in the powder form. A thin layer of the powder was placed on glass and oscillated on the table of a Hilger-Müller X-ray spectroscope. The X-ray spectra were received on photographic plates. A special form of gas X-ray-tube fitted with a copper anticathode was used as the source of X-rays. The rays were unfiltered so that both the K_α and K_β radiations of copper were present. The tube was operated by a Watson transformer, run at about 50,000 volts and 10 milliamperes.

(3) *Experimental Results.*

The following tables give the results of the measurements of the photos obtained in this way. The spacings are given in A.U. and should be accurate to about 1%. A rough estimate of the intensity of the various lines is also given; "s," "m" and "w" denote strong, medium and weak respectively. Lines which were obviously due to the K_β copper radiation have been omitted.

TABLE I. China Clay at 1,200°		TABLE II. China Clay 1,700°		TABLE III. Sillimanite	
Intensity	Spacing	Intensity	Spacing	Intensity	Spacing
m.	5·50	m.	5·48	m.s.	5·45
s.	3·42	s.	3·42	s.	3·41
				m.s.	3·36
w.	2·90	m.w.	2·90	m.w.	2·90
m.	2·72	m.	2·71	s.	2·68
m.s.	2·56	m.s.	2·56	m.	2·55
m.w.	2·46	m.w.	2·46	w.	2·42
w.	2·30			w.	2·35
s.	2·21	m.s.	2·22	s.	2·20
m.s.	2·13	m.	2·13	s.	2·11

TABLE IV.

Alumina.	
Intensity	Spacing
s.	3·48
s.	2·54
m.s.	2·37
s.	2·08
w.	1·94

TABLE V. China clay (1) + Alumina (1) 1,200°C		TABLE VI. China clay (1) + Alumina (1) 1,700°C		TABLE VII. China clay (1) + Alumina (2) 1,200°C.	
Intensity	Spacing	Intensity	Spacing	Intensity	Spacing
m.	5·47	m.	5·47	m.w.	5·48
m.s.	3·49				
s.	3·38	s.	3·41	s.	3·38
w.	2·86	v.w.	2·86	v.w.	2·86
w.	2·70	m.	2·70	m.	2·70
s.	2·54	m.s.	2·54	m.s.	2·54
w.	2·45				
w.	2·39	w.	2·36	w.	2·35
w.	2·30	w.	2·30	w.	2·30
m.	2·12	m.s.	2·20	m.	2·10
m.	2·08	m.s.	2·08	m.	2·08

TABLE VIII.

China clay (1) + Alumina (2) 1,700°C.

Intensity	Spacing
s.	7·16
w.	4·43
s.	3·57
m.	3·31
w.	3·08
w.	2·81
s.	2·56
m.	2·36
m.	2·33
m.	2·10
m.	2·07
m.	1·98

(4) *Discussion of Results.*

A comparison of Tables I, II, III shows immediately that the spectra of the two china clays are practically identical with each

other and with that of sillimanite. Within experimental error, lines occur in the same positions for the three substances. There are one or two slight differences between the spectra of sillimanite and those of the china clays which will be discussed later. There is no doubt that sillimanite is the principal crystalline constituent. Sillimanite shows a well marked doublet in the position 3·41, 3·38. The clays showed a rather broad strong line in this position. The breadth of the line suggested that it was probably two lines close together. This was tested by repeating the photographs under conditions which gave satisfactory dispersion. Under these conditions there was no doubt that there were two lines in this position also for the china clays. These photographs with high dispersion also verified the fact that the sillimanite and the china clays gave lines in the same position within experimental error for the range investigated.

The substances (c), (d) and (e) all gave very similar spectra. The results are shown in Tables V, VI and VII. These can be readily interpreted on the assumption that both free alumina and free sillimanite are the main crystalline constituents, the effect of the sillimanite being the more pronounced. Photographs with a higher dispersion confirmed this view. In the tables the various lines can readily be apportioned to either sillimanite or alumina.

The photographs obtained by the examination of (f) (china clay (1)+alumina (2) mols.) at 1,700°C.—show an entirely different spectrum. The results are shown in Table VIII. It is clear that some new crystal has been formed in this case. Whether sillimanite or alumina is present or not, it is difficult to say without more extensive experimental work, but it is certain that the principal crystalline constituent is something different and that if sillimanite or alumina is present it is only a very small quantity.

As stated above, there are certain small differences between the photographs given by the china clay and those of sillimanite. Repetition of the experiment seems to show that these differences are real and not due to experimental sources. They are connected not with the positions of the lines but with the distribution of intensity. The noticeable difference is in the line at 2·54 A.U. In the china clays this is a strong line, considerably stronger than the line at 2·71 for example. In sillimanite the line is of medium strength but considerably weaker than the 2·68 line. It is a significant fact that alumina gives a strong line at this position (see Table IV). If there were some free alumina in the china clays, it is to be expected that the line at 2·54 would be strong, since both sillimanite and alumina gave lines at this point. This in itself is not sufficient to establish the presence of alumina, but it suggests that it is a possibility. To decide the question a more prolonged investigation would be necessary.

The photographs do not give much indication as to the size of the crystals in the clay. All that can be said is that they are

neither very large nor very small (colloidal size). There is much more general fogging in the clay photographs than in those from sillimanite and alumina. This is probably due to a general scattering of the X-rays by a considerable quantity of non-crystalline material in the clays, in addition to the sillimanite.

Although these experiments yield a certain amount of information as to the crystalline nature of these compounds, further experimental work will be devoted to some of the questions involved. It is clear, however, that the X-ray analysis of such compounds should prove a valuable help in the interpretation of data obtained from other methods of investigation.

Davy Faraday Laboratory,
Royal Institution.

Risultati di Esperienze con Raggi X sulla Natura Cristallina delle Argille Porcellaniche, ecc.

Di G. Shearer, M.A., Ph.D.

(1) *Sostanze esaminate.*

Le seguenti sostanze furono esaminate con lo spettrometro a raggi X:

(*a*) Argilla porcellanica riscaldata a 1,200°.
(*b*) Argilla porcellanica riscaldata a 1,700°.
(*c*) Argilla porcellanica (1 mol. + allumina (1 mol) riscaldate a 1,200°.
(*d*) Argilla porcellanica (1 mol) + allumina (1 mol) riscaldate a 1,700°.
(*e*) Argilla porcellanica (1 mol) + allumina (2 mol) riscaldate a 1,200°.
(*f*) Argilla porcellanica (1 mol) + allumina (2 mol) riscaldate a 1,700°.
(*g*) Allumina riscaldata a 1,200°.
(*h*) Allumina riscaldata a 1,700°.
(*i*) Sillimanite naturale.

Queste tre ultime furono esaminate per vedere se esistesse o no nelle argille porcellaniche dell'allumina o della sillimanite libera.

(2) *Metodo sperimentale.*

Tutte le sostanze furono esaminate sotto forma di polvere. Un sottile strato di polvere venne posto su un vetro e fatto oscillare sulla tavola di uno spettroscopio a raggi X Hilger Müller. Gli spettri radioscopici furono fatti arrivare su delle placche fotografiche. Come sorgente radioattiva venne usato un tubo da gas radioattivo munito anticatodo di rame. I raggi non vennero filtrati, cosicchè tanto le radiazioni K_α come le K_β del rame si manifestarano. Il tubo venne fatto funzionare mediante un trasformatore Watson, a circa 50,000 volt e 10 millampere.

(3) *Risultati sperimentali.*

Le tavole che seguono danno i risultati delle misure delle fotografie ottenute in questo modo. Gli spazi sono espressi in A.U. e il grado di accuratezza dovrebbe essere di circa 1%. E' data anche la graduazione approssimata delle intensità delle diverse linee: "f," "m" e "d" denotano forte, medio e debole rispettivamente. Le linee che erano evidentemente dovute alle radiazioni K_β del rame sone state omesse.

TAVOLA I. Argilla porcellanica a 1200°		TAVOLA II. Argilla porcellanica a 1700°		TAVOLA III. Sillimanite	
Intensità	Spazi	Intensità	Spazi	Intensità	Spazi
m.	5·50	m.	5·48	m.f.	5·45
f.	3·42	f.	3·42	f.	3·41
				m.f.	3·36
d.	2·90	m.d.	2·90	m.d.	2·90
m.	2·72	m.	2·71	f.	2·68
m.f.	2·56	m.f.	2·56	m.	2·55
m.d.	2·46	m.d.	2·46	d.	2·42
d.	2·30			d.	2·35
f.	2·21	m.f.	2·22	f.	2·20
m.f.	2·13	m.	2·13	f.	2·11

TAVOLA IV.

Alumina.	
Intensità	Spazi
f.	3·48
f.	2·54
m.f.	2·37
f.	2·08
d.	1·94

TAVOLA V. Argilla porcellanica (1) + Allumina (1) a 12000°		TAVOLA VI. Argilla porcellanica (1) + Allumina (1) a 1700°		TAVOLA VII. Argilla porcellanica (1) + Allumina (2) a 1200°	
Intensità	Spazi	Intensità	Spazi	Intensità	Spazi
m.	5·47	m.	5·47	m.d.	5·48
m.f.	3·49				
f.	3·38	f.	3·41	f.	3·38
d.	2·86	v.d.	2·86	v.d.	2·86
d.	2·70	m.	2·70	m.	2·70
f.	2·54	m.f.	2·54	m.f.	2·54
d.	2·45				
d.	2·39	d.	2·36	d.	2·36
d.	2·30	d.	2·30	d.	2·30
m.	2·12	m.f.	2·20	m.	2·10
m.	2·08	m.f.	2·08	m.	2·08

TAVOLA VIII. Argilla porcellanica (1) + Allumina (2) a 1700°	
Intensità	Spazi
f.	7·16
d.	4·43
f.	3·57
m.	3·31
d.	3·08
d.	2·81
f.	2·56
m.	2·36
m.	2·33
m.	2·10
m.	2·07
m.	·198

(4) *Discussione dei risultati.*

Un confronto delle tabelle I, II, III mostra immediatamente che gli spettri delle due argille porcellaniche sono identici fra di loro e con quello della sillimanite. Le linee capitano nella stessa posizione per le tre sostanze nei limiti di errori sperimentali.

Vi sono una o due leggere differenze fra gli spettri della sillimanite e quelli delle argille porcellaniche ed esse saranno discusse più avanti. Non v'è dubbio che la sillimanite è il principale costituente cristallino. La sillimanite mostra un doppio ben marcato nella posizione 3·41, 3·38. Le argille mostrarono una linea piuttosto larga e forte in questa posizione. La larghezza della linea fece supporre che si trattasse probabilmente di due linee riunite insieme. Si fece la prova rifacendo le fotografie in condizioni che diedero dispersione soddisfacente. In tali condizioni non v'era dubbio che si trattava di due linee in questa posizione anche per le argille porcellaniche. Queste fotografie ad alto coefficiente di dispersione verificarono anche il fatto che la sillimanite e le argille porcellaniche davano linee nella medesima posizione dentro i limiti di errori sperimentali per la zona studiata.

Le sostanze (c), (d) ed (e) diedero tutte spettri molto simili. I risultati sono mostrati nelle tabelle V, VI e VII. Queste possono essere di immediata interpretazione in base al presupposto che, tanto l'allumina libera come la sillimanite libera, sono i principali costituenti cristallini, e chè l'effetto della sillimanite è il più pronunziato. Delle fotografie con un grado maggiore di dispersione confermarono questa opinione. Nelle tabelle le diverse linee sono state assegnate o alla sillimanite o all'allumina.

Le fotografie ottenute dall'esame di (f)—argilla porcellanica (1)—allumina (2 mol) a 1,700°—mostrano uno spettro completamente diverso. I risultati sono esposti nella Tavola VIII. E' chiaro chè in questo caso sono stati formati dei nuovi cristalli. E' difficile dire, senza del lavoro sperimentale ulteriore se la sillimanite o l'allumina siano presenti o no, ma è certo che il principale costituente cristallino è in certo modo diverso e che se la sillimanite e l'allumina sono presenti, lo sono soltanto in quantità molto piccola.

Come s'è detto sopra vi sono alcune piccole differenze fra le fotografie date dall'argilla porcellanica e dalla sillimanite. Una ripetizione degli esperimenti sembra mostrare che tali differenze sono effettive e non son dovute a cause sperimentali. Esse non dipendono dalla posizione delle linee ma dalla distribuzione dell'intensità. La differenza che può notarsi è nella linea a 2·45 A.U. Nelle argille porcellaniche questa è una linea forte e considerevolmente più forte della linea a 2·71 per esempio. Nella sillimanite la linea è di media forza, ma considerevolmente più debole della linea 2·68. E' un fatto significante che l'allumina dà una linea forte in questa posizione (Ved. Tav. IV). Se vi fosse dell'allumina libera nelle argille porcellaniche dovrebbe aspettarsi che la linea nel punto 2·45 fosse forte, poichè tanto la sillimanite come l'allumina danno linee in questo punto. Questo non è sufficiente da se stesso a stabilire la presenza dell'allumina, ma fa pensare che v'è la possibilità. Per potersi pronunziare de-

finitivamente in merito sarebbe necessario condurre degli esperimenti ulteriori.

Le fotografie non danno molte indicazioni in merito alla grandezza dei cristalli nell'argilla. Tutto quel che si può dire è che essi non sono nè molto grandi nè molto piccoli. (dimensioni colloidali). V'è più annebbiamento nelle fotografie dell'argilla che in quelle della sillimanite e dell'allumina. Questo è dovuto probabilmente allo spargimento generale dei raggi X per la notevole quantità di scstanze non cristalline nelle argille, in aggiunta alla sillimanite.

Se da una parte queste esperienze contribuiscono a fornire una certa quantità di informazioni in merito alla natura cristallina di questi composti dell'ulteriore lavoro sperimentale verrà eseguito su alcune delle questioni discusse. E' chiaro però che l'analisi radioscopica di tali composti sarebbe di grande aiuto nello studio dei dati ottenuti da altri metodi di investigazione.

Laboratorio Davy Faraday del
Reale Istituto.

XXVII.—The Action of Heat on Kaolinite and other Clays.†—I.*

By J. W. Mellor and A. Scott.

[Communication from the Clay and Pottery Laboratory, Stoke-on-Trent, No. 112.]

THE action of heat on kaolinite has proved to be exceedingly complex. H. le Chatelier[1] first showed that when heat is applied to this substance, at a uniform rate, there is retardation in the rate of rise of temperature of the kaolinite in the vicinity of 500° and an acceleration in the vicinity of 900°. Le Chatelier's results were obtained by the use of a thermocuple and mirror galvanometer. J. W. Mellor and co-workers studied the phenomenon in more detail and measured the effects by means of a recording pyrometer. The pyrometer chart showed le Chatelier's retardation as a terrace on the heating curve of the kaolinite, and his acceleration as a hump.

In the last decade numerous papers describing similar experiments have appeared, and these, in the main, confirm the results already obtained, the chief critical points being those at 500° and 900-1,000°. Some writers, notably Satoh, have found other critical points but these will be discussed later.

1. *Dehydration of Kaolinite.*

Although the terrace which occurs on the heating curve about 500° is interpreted by different workers in different ways, there is no reason for doubting its connection with the dehydration of the kaolinite. In the neighbourhood of this temperature the mineral breaks down with the evolution of the combined water. It has been stated by P. Schemjatschensky[2] and others that no water is lost by kaolinite at low temperatures but this is contradicted by the work of J. W. Mellor and A. D. Holdcroft[3], A. E. Wülfing, G. Keppeler, and G. Tammann and W. Pape, who have demonstrated that there is no definite temperature at which the water is evolved. The lower the temperature the slower is the speed of dehydration; nevertheless even at ordinary atmospheric temperatures a loss of water can be detected under the correct conditions. Between 500° and 600°C the speed at which the water is given off is so great that the heat effect (absorption) produces a marked lowering of the temperature. The water which is evolved at low temperatures can be restored and hence the reaction is reversible and may be symbolized $Al_2O_3.2SiO_2.2H_2O \rightleftharpoons Al_2O_3.2SiO_2+2H_2O$.[4]. The suggestion of W. Vernadsky and F. Hundeshagen[5] that the water is evolved in two stages, one half being given off at a lower temperature than the

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†For references see end of paper.

other, is most improbable, as the continuity of the evolution of the water has been demonstrated by the work of Mellor and Holdcroft which also refutes the theory advanced by E. Löwenstein that one-half molecule of water can be driven off at a low temperature. Similarly the application by G. Keppeler of the term hygroscopic to the water which is lost when kaolin, previously dried at 110°, is allowed to stand over concentrated sulphuric acid, is not justifiable; nor is the inference of J. M. van Bemmelen, and S. J. Thugutt that one of the two molecules of water is not chemically combined. There is likewise no experimental evidence in favour of the view that the water in kaolinite is "zeolitic" in character.

2. *Nature of Decomposition of Kaolinite at* 500°.

Many suggestions regarding the nature of the residue left after the clay is dehydrated have been advanced. The properties of this residue have been compared by J. W. Mellor and A. D. Holdcroft with those of artificially prepared alumina and a remarkable correspondence has been noted with regard to (*a*) the variation of the specific gravity; (*b*) the hygroscopicity; (*c*) the solubility in acids; and (*d*) the exothermic change indicated by the heating curve about 900°. It has, therefore, been assumed that, in the decomposition of clay, the products are free silica, free alumina and water, and that the breakdown is symbolized—$Al_2O_3.2SiO_2.2H_2O \rightarrow Al_2O_3 + SiO_2 + 2H_2O$. This view has been adopted by G. Tammann and W. Pape, G. Keppeler, R. Rieke, and many others. As further evidence of the presence of free alumina in the residue, it may be noted that G. Tammann and W. Pape found that the dissociation temperatures of the alkaline earth carbonates were lowered to the same extent by alumina and dehydrated kaolinite.

Among other hypotheses which have been advanced the following may be briefly noted. J. Samoilov stated that the decomposition results in the formation of sillimanite, free silica and water according to the equation $Al_2O_3.2SiO_2.2H_2O \rightarrow Al_2O_3\ SiO_2 + SiO_2 + 2H_2O$. W. Vernadsky and F. W. Clarke[6] assume that the residual solid product is leverrierite, or the anhydride of kaolinite, which develops in the reaction—$Al_2O_3.2SiO_2.2H_2O \rightarrow Al_2O_3.2SiO_2 + 2H_2O$, while Knote suggested the formation of $Al_2O_3.SiO_2$ and $Al_2O_3.3SiO_2$ by the dehydration of kaolin. V. Agafonoff and W. Vernadsky have maintained, on the basis of microscopic examination, coupled with their inability to separate the material into two fractions by means of heavy liquids, that the product of the dehydration of kaolinite is homogeneous. The answer to the first of these is that the microscope is quite unable to distinguish amorphous substances so much alike as alumina and silica. Their further claim that the material, after heating to 500°—600°, is birefringent and optically negative is refuted, so far as the dehydration product is concerned, by the work of Shearer[7] who, as stated

below, has demonstrated by means of X-radiograms, that the dehydrated product is devoid of crystalline structure except for the presence of traces of undecomposed kaolinite. The argument that the material must be homogeneous because it cannot be separated into two fractions by means of heavy liquids involves the assumptions (*a*) that it is possible to deflocculate and separate the particles of alumina and silica (which are most probably aggregated in dehydrated kaolinite) and (*b*) that the specific gravity of each component is known. It may be added that a much more delicate test, namely, the elutriation of the dehydrated material, has been tried by us and has failed to give any separation. Vernadsky's comparision of the behaviour of kaolinite with that of artificial mixtures contributes no information as even the best mixture obtained by grinding together the constituent oxides is very crude compared with that furnished by the decomposition of kaolinite. No value can be attached to the negative results of any of the above mentioned experiments, as the results are capable of explanation in several ways; they lead us into a *cul de sac* and have no value in view of the positive results of the chemical and physical tests summarised in the present paper.

O. Rebuffat's deduction, from the behaviour of dehydrated clay when it is mixed with lime to form cements, that the silica and the alumina must be combined, is invalidated by the arguments given above with reference to Vernadsky's experiments, while the former author's inference that, because sillimanite can be formed in the absence of an added flux at relatively low temperatures, the silica and the alumina cannot be free, is valueless in view of the large array of data which demonstrate not only general reactions between solids, but also the specific combination of alumina and silica at such temperatures.

S. Satoh argued that the breakdown of the kaolinite molecule occurred in two stages, a dehydration between 450° and 650°—$Al_2O_3.2SiO_2.2H_2O \rightarrow Al_2O_3.2SiO_2+2H_2O$—and a decompostion of the anhydride at 650°-700°—$Al_2O_3.2SiO_2 \rightarrow Al_2O_3+2SiO_2$. Satoh's results, which were based on a differential method using quartz sand as the inert substance are vitiated by the fact that the thermal changes of the latter in the neighbourhood of 575° were not taken into account. In a later paper by the same author (1923) it is stated that similar results are obtained using calcined alumina and calcined felspar as the inert substances and that the mineral dissociated at 650° into an aluminium silicate and free silica. No experimental justification of this change of opinion is given. C. E. Moore has given an elaborate explanation of the dehydration based on the hexite-pentite theory, but the obvious objections to the latter dispose of the theory advanced by this author.

The adoption of any of these hypotheses concerning the nature of the dehydrated kaolinite renders it necessary to make the assumption that leverrierite, or sillimanite, or any other alumium

silicate which may be suggested, possesses the above-mentioned four properties in common with alumina; such an assumption seems to us to be extremely improbable. The decomposition into the free oxides is also indicated by the X-ray examination of kaolinite[8] which has been dehydrated at 700°. The X-radiogram of such material shows that the product is in the amorphous condition, the only detectable crystalline substance present being a trace of undecomposed kaolinite. Decomposition into the free oxides, silica, alumina and water is the only one which satisfactorily explains the facts. Chemical verification of this hypothesis is furnished by the experimental work of A. N. Sokolov,[9] who found, that by treating, with hydrochloric acid, kaolinite which had been heated to various temperatures the molecular ratio of the soluble alumina to the water lost in the heat-treatment was constant and approximated to 1; 2, the ratio in which the two oxides occur in kaolinite.

Between 500° and 900°, several other critical points have been reported. H. S. Houldsworth and J. W. Cobb,[10] on the basis of dilatometric measurements, found that contractions occurred at 680°—710° and at 870° but no corresponding terraces or humps have been observed on the heating curves. P. Braesco had previously described similar effects at temperatures ranging from 630°—840°. A similar remark applies to the contraction noted by Moore at 700°—740°. According to S. Satoh, the endothermic change covers the temperature range, 450°—700°. Small discrepancies in the observed temperatures of dehydration must occur, however, for the reasons stated above; that the conditions of the experiment, especially the rate of heating, influence the results to an appreciable extent.

3. *Nature of Transformation between* 900° *and* 1,060°.

As stated above, the hump on the heating curve about 900°. is due to a change in the alumina set free during the dehydration of the clay. J. W. Mellor compared the behaviour of synthetic alumina with that of kaolinite and found that they agreed in several respects, a fact recently confirmed by G. Tammann and W. Pape.

This hump is not a definite transition temperature; the observed temperature depends on the rate at which the kaolinite is heated. The hump represents a reaction attended by the evolution of heat. A similar reaction occurs with a number of other oxides *e.g.*, ferric oxide, chromic oxide, zirconia. In the case of alumina the calorescence is usually explained by assuming that the molecule of alumina is poylmerized at this temperature. Whatever be the molecular character of the change it is attended by marked changes in such properties of the alumina as (*a*) specific gravity; (*b*) hygroscopicity; and (*c*) solubility in acids. We consider it probable that the amorphous alumina passes at this temperature

into the crystalline form. This transformation has been found by different workers to occur at various temperatures between 900° and 1,060°. The discrepancies in the temperature of this transformation, as determined by various observers, is probably due to a combination of causes. The condition of the amorphous alumina as far as grain-size is concerned will probably affect the temperatute of crystallization, as also will the proportion of other materials which may be present and act as fluxing agents. The presence of the latter may accelerate the change just as they accelerate the formation of sillimanite at higher temperatures. The rate of heating, as stated above, also has an influence. The assumption made by W. Vernadsky that the hump at 900° is due to a transformation or decompostion is entirely hypothetical as a corresponding critical point has not been found with the natural forms of the latter. A similar remark applies to Satoh's assumption that a change in an aluminum silicate is responsible for the hump.

4. *Formation of Sillimanite.*

At rather higher temperatures the product shows the definite crystalline form characteristic of the aluminium silicate called sillimanite. This is demonstrated by microscopic examination and by the X-ray spectrum. The observations of G. Shearer on china clay and mixtures of that mineral and alumina, which have been calcined at 1·200°, show the presence of both sillimanite and corundum, the amount of the former being much greater than that of the latter in the samples of heated kaolinite. A comparison of the X-radiogram of sillimanite from a porcelain body with that of the natural mineral (Indian) indicated a very close agreement between the two substances, and confirmed the chemical identity mentioned below.

The higher the temperature of ignition the greater is the proportion of material transformed into sillimanite. The transformation is also favoured by the presence of fluxes such as felspar.

Numerous observers have reported the formation of sillimanite during the firing of porcelain bodies. Thus the occurrence of acicular crystals was recorded by C. G. Ehrenberg[11] as early as 1836 and also by A. Oschatz and K. Wächter in 1847. H. Behrens observed the devitrification of the groundmass of porcelain and noted that the crystalline part was less soluble in hydrofluoric acid than was the remainder. A. Bünzli states that porcelain contained crystals of aluminum silicate low in, or free from, potash. E. Hussak noted the formation in porcelain of fine needles which seemed to be sillimanite and also obtained them by the prolonged heating of clay at 1,400°. J. W. Mellor described the occurrence of sillimanite in various types of pottery, including some which has been heated to a temperature of less than 1,200°. Sillimanite has also been identifed in fired clays and synthetic mixtures by A. Zöllner, M. Glasenapp, E. Plenske, A. S. Watts, A. A. Klein and many others. It is interest-

ing to note that J. W. Mellor and A. Heath observed that the crystals were copiously formed with a mixture of kaolin and felspar which was fired in a pottery oven below 1,200°. The sillimanite obtained in such a way has been separated from the remainder of the material by hydrofluoric acid, and analyses show that the composition agrees approximately with that of the natural mineral. The following table gives the results obtained by several observers.

MOLECULAR RATIO OF SILICA TO ALUMINA IN ARTIFICIAL SILLIMANITE.

Observer	Natural Mineral	Mellor	Zöllner	Mellor and Scott		
				Kaolinite	Ka + Al_2O_3	Fireclay
Silica ..	1·00	1·00	1·00	1·00	1·00	1·00
Alumina ..	1·00	1·03	1·02–1.11	1·09	1·13	1·06

5. *Formation of "Keramite."*

Several writers have reported that the sillimanite obtained by the heating of fireclay had given the same composition as the natural mineral. W. Vernadsky[12] found that there was more alumina than required for the unit molecular relation while A. H. Cox has reported that when a piece of Stourbridge Fireclay is heated to a temperature of approximately 1,700°, the formula of the compound insoluble in cold hydrofluoric acid is $11Al_2O_3.8SiO_2$. It may be noted that H. St. C. Deville and H. Caron found a similar compound by the action of alumina fluoride and silica. Recently we have examined kaolin and mixtures of kaolin and alumina heated at various temperatures between 1,200° and 1,700°, and we have found that the insoluble residue left after treatment with hydrofluoric acid has the composition of sillimanite at the lower temperatures, but after heating to 1,700° the composition tends to approximate to $3Al_2O_3.2SiO_2$. The following table gives the data.

MOLECULAR PROPORTIONS OF SILICA AND ALUMINA IN "KERAMITE," ETC.

	1200°	1500°	1700°
Silica	1·00	1·00	1·00
Alumina	1·09	1·47	1·55

The results so far obtained give some evidence of the existence of solid solution between the two compounds $Al_2O_3.SiO_2$ and $3Al_2O_3.2SiO_2$.

The freezing point curves of the binary system, alumina—silica, as determined by E. S. Shepherd and G. A. Rankin, show that the sillimanite is stable in contact with the melt and is the only compound of these two oxides which is formed. However, the recent redetermination (not yet published) by N. L. Bowen and J. W. Grieg of

the freezing point curve shows that at temperatures above 1,400° the stable form is $3Al_2O_3.2SiO_2$, no mention being made on the diagram of the compound which corresponds to natural sillimanite. This contradicts the results obtained by Shearer and discussed in the next paper. Shearer has found that the X-radiogram of kaolinite which has been calcined at 1,700° shows the lines which are obtained with natural sillimanite and hence it is possible to suppose that this heated product contains natural sillimanite. Similar results are obtained with a mixture of one gram-molecule of kaolinite and one of alumina fired to the same temperature. The X-radiogram of a mixture of one gram-molecule of kaolinite and two gram-molecules of alumina, however, shows the presence of an entirely new compound of low crystalline symmetry, and it is very probable that this corresponds with $3Al_2O_3.2SiO_2$ as this is the composition of the mixture. From the results which have been obtained so far it seems probable that, under the conditions which obtain when fire-clays are heated to a temperature of 1,700°, sillimanite is the main compound formed, but in most cases a certain amount of the $3Al_2O_3.2SiO_2$ compound is also present. Under special circumstances the new compound $3Al_2O_3.2SiO_2$ seems to develop. It may be noted that in all cases, even where there is an excess of silica, Shearer's X-radiograms have shown the presence of free alumina in all the samples examined. The exact nature of the compounds formed remains a matter for future work.

It would be convenient to give this latter substance a name and we therefore suggest "Keramite." For those who are fond of constitutional formulæ we have the following for sillimanite and keramite.

$$O{=}Si{<}\begin{matrix}AlO_2\\AlO_2\end{matrix} \qquad\qquad O{<}\begin{matrix}Si\ (AlO_2)_3\\Si\ (AlO_2)_3\end{matrix}$$

Sillimanite, Al_2SiO_5. Keramite, $Al_6Si_2O_{13}$.

Summary.

The following are the conclusions reached in this paper:—

1. The dehydration of kaolinite does not take place at a fixed temperature and is completed above 500°.
2. Kaolinite when heated to just above 500° decomposes into free silica, free alumina and water.
3. The critical point in the neighbourhood of 900° is connected with a transformation in the form of the alumina.
4. Sillimanite of the same composition as the natural mineral can develop at temperatures below 1,200° and probably above that temperature forms solid solutions with $3Al_2O_3.2SiO_2$.
5. A new compound is formed when kaolinite is heated to 1,700°. This may be $3Al_2O_3.2SiO_2$.

NOTE—Since the above was written a paper has appeared in which the compound $3Al_2O_3$, $2SiO_2$ has been named mullite, by N. L.

Bowen, and J. W. Grieg, (*Amer. Cer. Soc.*, **7**, 238, 1924; *Jour., Washington Acad. Sci.*, **14**, 183, 1924) the name being derived from the natural occurrence of the material in Mull.

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L'Azione del Calore sulla Caolinite I.*

di J. W. Mellor e A. Scott.

L'AZIONE del calore sulla caolinite è dimostrato essere estremamente complessa. H. le Chatelier[1] mostrò per il primo che quando il calore è applicato a questa sostanza, in misura uniforme, vi è ritardo nel grado di aumento della temperatura della caolinite in prossimità di 500° ed accelerazione in prossimità di 900°. I risultati di Chatelier furono ottenuti mediante l'uso di una coppia termo-elettrica e di un galvanometro a specchio. J. W. Mellor e i suoi collaboratori studiarono il fenomeno più dettagliatamente e re misurarono gli effetti mediante un pirometro registrante. Il diagramma pirometrico mostrò il ritardo di le Chatelier sotto forma di ripiano nella curve di riscaldamento e l'accelerazione sotto forma di gobba.

Durante gli ultimi dieci anni sono apparse numerose memorie descriventi tali esperimenti ed esse confermano in massima i risultati già ottenuti, che i punti critici principali sono quelli a 500° ed a 900-1,000°. Alcuni scrittori, notevole fra i quali il Satòh hanno trovati altri punti critici ma questi saranno discussi in seguito.

1. *Disidratazione della caolinite.*

Sebbene il ripiano che appare nella curva di riscaldamente verso i 500° sia interpretato da diversi esperimentatori in diversmaniere, non v'è ragione di dubitare del suo legame colla disidratao zione della caolinite. In prossimità di questa temperatura il minerale si sminuzze col movimento dell'acqua combinata. E' stato dichiarato da P. Schemjatschensky[2] e da altri chè non si perde acqua per caolinite a basse temperature, ma questo è contraddetto dai lavori di J. W. Mellor e A. D. Holdcroft[3], A. E. Wülfing, G. Keppeler, e G. Tamman e W. Pape, i quali hanno dimostrato che non v'è una temperatura definita alla quale l'acqua si evolve. Più bassa è la temperatura e più bassa la velocità di disidratazione; nondimeno anche alle temperatura atmosferiche ordinarie la perdita d'acqua può essere osservata nelle esatte condizioni. Fra 500° e 600° la velocità alla quale l'acqua viene emessa è cosigrande che l'effetto del calore (assorbimento) produce un marcato abbassamento della temperatura. L'acqua che viene emessa a bassa temperatura può essere restituita e quindi la reazione èreversibile e può essere simbolizzata cosi: $Al_2O_3.2SiO_2.2H_2O$, $Al_2O_3.2SiO_2$-$2H_2O$.[4] Il suggerimento di W. Vernadsky ed F. Hundeshagen[5] che l'evoluzione dell'acqua avviene in due fasi, e che cioè una metà viene emessa a più bassa temperatura

*Stampato col permesso del consiglio della British Refractories Research Association.

L'opere consultate rispettive agli articoli si trovano a capo del testo inglese.

dell'altra e più che improbabile, poichè la continuità dell' evoluzione dell'acqua è stata dimostrata dal lavoro di Mellor e Holdcroft che respinge anche la teoria avanzata de E. Löwenstein che mezza molecola d'acqua venga emessa a bassa temperatura. Ugualmente l'applicazione fatta da G. Keppeler dell'igroscopio termico all'acqua che vien perduta alorochè il caolino seccato precedentemente a 110° vien fatto rimanere sull'acido solforico concentrato, non è giustificabile; nè lo è neppure la deduzione di J. M. van Bemmelen e S. J. Thugutt che una delle due molecole d'acqua non sia chimicamente combinata.

2. *Natura della decomposizione della caolinite a* 500°.

Sono state avanzate molte ipotesi relativamente alla natura del residuo lasciato dopo che l'argilla è stata disidratata. Le proprietà di questo residuo sono state paragonate da J. W. Mellor è A. D. Holdcroft con quelle dell'allumina preparata artificialmente ed é stata notata una notevole corrispondenza per ciò che riguarda: (*a*) la variazione della densità specifica; (*b*) l'igroscopicità; (*c*) la solubilità negli acidi e (*d*) il cambic asotermico indicato dalla curva di riscaldamento a circa 900°. E'stato perciò supposto che nella decomposizione dell'argilla i prodotti sono silice libera, allumina libera ed acqua e che il disgregamento è simbolizzato da $Al_2O_3.2SiO_2.2H_2O \rightleftharpoons Al_2O_3.SiO_2.+2H_2O$. Questa opinione è statà adottata da G. Tamman e W. Pape, G. Keppeler, R. Rieke e molti altri. Come ulteriore dimostrazione della presenza dell'allumina libera nel residuo può notarsi che G. Tamman e W. Pape trovarono che le temperature di dissociazione dei carbonati ternosi alcalini erano abbassate in ugual misura dall'allumina e dalla caolinite disidrata.

Fra le altre ipotesi avanzate può essere notata brevemente la seguente. J. Samoilov stabili che la decomposizione risulta nella formazione di sillimanite, silice libera ed acqua in conformità dell' equazione $Al_2O_3.2SiO_2.2H_2O \rightarrow Al_2O_3.SiO_2+SiO_2+2H_2O$. W. Vernadsky ed F. W. Clarke[6] suppongono che il prodotto solido residuale sia leverrierite o l'anidride della caolinite che si sviluppa nella reazione $Al_2O_3.2SiO_2.2H_2O \rightarrow Al_2O_3.2SiO_2+2H_2O$, mentre Knote suggerisce la formazione di $Al_2O_3.SiO_2$ ed $Al_2O_3.3SiO_2$ per la disidratazione del caolino. V. Agafonoff e W. Vernadsky hanno sostenuto, in base alláesame microscopico accoppiato all'impossibilità nella quale essi si sono trovati di separare il materiale in due parti per mezzo di liquidi pesanti, che il prodotto della disidratazione della caolinite è omogeneo. La risposta al primo di questi fatti è che il microscopio non permette affatto di distinguere delle sostanze amorfe tanto simili come l'allumina e la silice. Il loro sostenere inoltre che il materiale dopo un riscaldamento a 500-600 è birefrangente ed otticamente negativo è confutato, per ciò che concerne il prodotto disidratato, dal lavoro di Shearer[7]; che, come detto appresso, ha dimostrato per mezzo di radiografie che il prodotto disidratato

non contiene struttura cristallina salvo la presenza di tracce di Caolinite indecomposta. L'argomentare che il materiale deve essere omogeneo perchè non può essere separato in due frazioni mediante liquidi pesanti involve le seguenti supposizioni: (*a*) Che è possibile sfioccare e separare le particelle di allumina e silice (le quali sono con tutta probabilitá raggruppate nella caolinite disidratata) e (*b*) Che la gravitá specifica di ciascun componente sia conosciuta. Potrebbe aggiungersi che una prova molto più delicata, e cioè la purificazione idraulica del materiale disidratato è stata tentata da noi ma non è riuscita a dare alcuna separazione. Il paragone portato da Vernadsky fra il comportamento della caolinite con quello delle miscele artificiali non fornisce alcuna informazione, poichè anche la migliore miscela ottenuta dal macinare insieme gli ossidi costituenti è molto rozza in paragone di quella ottenuta dalla decomposizione della caolinite. Non può darsi alcun valore ai risultati negativi di qualsiasi degli esperimenti di cui sopra, perchè tali risultati si possono spiegare in varie maniere; essi ci conducono in un "cul de sac" (vicolo cieco) e non hanno valore considerando i risultati positivi delle prove chimiche e fisiche condensate in questa memoria.

La deduzione di O. Rebuffat, in base al comportamento dell'argilla disidratata allorchè vien mescolata con calce per formare i cementi, che la silice e l'allumina debbono essere combinate, viene infirmata dagli argomenti su esposti in merito agli esperimenti di Vernadsky, mentre l'inferenza del primo che la silice e l'allumina non possono essere libere perchè la sillimanite può essere formata nell'assenza di un fondente addizionale, è senza valore in vista del gran numero di dati che dimostrano non solo le reazioni generali fra i solidi, ma anche la combinazione specifica dell'allumina e della silice a tali temperature.

S. Satoh suppose che la disgregazione della molecola di caolino si verificasse in due fasi, una disidratazione fra 450° e 650°—$Al_2O_3.2SiO_2.2H_2O \rightarrow Al_2O_3.2SiO_2+2H_2O$—ed una decomposizione dell'anidride a 650-700°—$Al_2O_3.2SiO_2 \rightarrow Al_2O_3+2SiO_2$. I risultati di Satoh che furono basati sul metodo differenziale usando sabbia di quarzo come sostanza inerte, sono viziati dal fatto che i cambiamenti termici del medesimo in prossimità di 575° non furono tenuti in conto. In una memoria posteriore (1923) dello stesso autore è dichiarato che risultati simili sono ottenuti usando allumina calcinata e felspato calcinato come sostanze inerti è che il minerale si dissociò a 650° in silicato di allumina e silice libera. Diquesto cambiamento di opinione non è data alcuna giustificazione sperimentale. C. E. Moore ha dato una spiegazione elaborata della disidratazione basata sulla teoria exite-pentite ma le obbiezioni ovvie all'ultima fanno cadere la teoria avanzata da questo autore.

L'adozione di qualunque di queste ipotesi concernenti la natura della caolinite disidratata rende necessario supporre che la

leverrierite o sillimanite o qualsiasi altro silicato di allumina che possa essere suggerito possegga le su menzionate quattro proprietà in comune con l'allumina; tale supposizione sembra a noi estremanmete improbabile. La decomposizione negli ossidi liberi è anche indicata dall'esame radioscopico della caolinite[8] che è stata disidratata a 700°. La radiografia di tale materiale mostra che il prodotto è nella condizione amorfa e che l'unica sostanza cristallina presente che sia discernibile è costituite da tracce di caolinite indecomposta. La decomposizione negli ossidi liberi, silice, allumina ed acqua è lunica che possa soddisfare questi fatti soddisfacentemente. La verifica chimica di questa ipotesi è fornita dal lavoro sperimentale di A. N. Sokolov[9] che trovo che trattando con acido idroclorico della caolinite che era stata riscaldata a varie temperature la proporzione molecolare di allumina solubile all'acqua perduta nel riscaldamento era costante e approssimatamente nella misura di 1 : 2, che è la proporzione nella quale i due ossidi si trovano nella caolinite.

Fra 500° e 900° sono stati notati diversi altri punti critici. H. S. Houldsworth e J. W. Cobb[10] sulla base delle misure dilatometriche trovarono che le contrazioni si verificavano a 680-710° ed a 870° ma non si sono riscontrate sulle curve corrispondenti ripiani nè gobbe. P. Braesco aveva descritti precedentemente tali effetti per temperature varianti da 630°a 840°. Una simile osservazione si applica alla contrazione notata da Moore a 700-740°. Secondo S. Satoh il cambiamento endotermico copre l'estensione delle temperature da 450° a 700°. Piccole discrepanze nelle temperature osservate della disidratazione debbono non per latro, per le ragioni su esposte, verificarsi, e cioè perchè le condizioni dell'esperienza, specialmente il grado di riscaldamento influenzano i risultati in misura apprezzabile.

3. *Natura della trasformazione fra* 900° *e* 1,060°.

Come s'è detto sopra la gobba nella curva di riscaldamento a circa 900° è dovuta ad un cambiamento nell'allumina resa libera durante la disidratazione dell'argilla. J. W. Mellor confrontò il comportamento dell'allumina sintetica con quello della caolinite e trovò che essi erano concordanti sotto molti punti di vista, fatto questo che è stato confermato recentemente da G. Tamman è W. Pape.

La gobba non rappresenta una temperatura di transizione definitiva; la temperatura osservata dipende dalla proporzione in base alla quale la caolinite e riscal data. La gobba rappresenta una reazione assistita dall'evoluzione del calore. Una simile reazione si presenta con parecchi altri ossidi, per esempio ossido ferrico, ossido cromico, zirconio. Nel caso dell'allumina la calorescenza è spiegata generalmente col supporte che la molecola di allumina sia polimerizzata a questa temperatura. Qualunque sia il carattere molecolare del cambiamento esso e contrassegnato

da cambiamenti distinti nelle seguenti proprietà dell'allumina: (*a*) densita specifica; (*b*) igroscopicita; e (*c*) solubilita negli acidi. Noi crediamo sia probabile che l'allumina amorfa passi nella forma cristallina a questa temperatura. Questa trasformazione e stata trovata da diversi sperimentatori verificantesi a temperature varie fra 900° e 1,060°. Le discrepanze nelle temperature di questa trasformazione, quali trovate dai diversi osservatori sono probabilmente dovute a cause concomitanti. La condizione dell'allumina amorfa per ciò che riguarda la grossezza della grana effetterè probabilmente la temperatura di cristallizzazione e lo stesso faranno in proporzione gli altri materiali chepossano essere presenti ed che agiscano come agenti di flusso. La presenza degli ultimi può accelerare il cambiamento cosi come essi accelerano la formazione della sillimanite a temperature più alte. La misura del riscaldamento ha, anche, come si è detto sopra, la sua influenza. La supposizione fatta da W. Vernadsky che la gobba a 900° sia dovuta ad una trasformazione o decomposizione è interamente ipotetica perche il punto critico corrispondente non è stato trovato nelle forme naturali di essi. Una simile osservazione si applica alla supposizione di Satoh che cioè un cambiamento in qualche silica to di allumina sia la causa della gobba.

4. *Formazione della Sillimanite.*

A temperature piùttosto alte il prodotto mostra la forma cristallina definitiva che è caratteristica delsilicato di allunina chiamato sillimanite. Questa è dimostrato dall'esame microscopico è dallo spettro radioscopico. Le osservazioni di G. Shearer sull'argilla porcellanica e sulle mescolanze di tale minerale coll'allumina calcinate a 1,200° mostrano la presenza di ambedue allumina è corundum, essendo la quantità della prima mol to maggiore di quella del secondo nei campioni di caolinite riscaldata. Un confronto fra la radiografia della sillimanite de corpo porcellanico con queela di an minerale naturale (Indiano) mostrò un accordo molto intimo fra le due sostanze è confermò l'identità chimica summenzionata.

Quanto più alta è la temperatura di ignizione maggiore è la proporzione di materiale trasformato in sillimanite. La trasformazione è anche favorita dalla presenza di flussi quali per esempio il felspato.

Numerosi sperimentatori hanno ripostata la formazione di sillimanite durante l'accensione di corpi porcellanici. Cosi la presenza di cristalli aghiformi fu riportata da C. G. Ehrenberg[11] non più tardi del 1,836 ed anche da A. Oschatz e K. Wächter nel 1847. H. Behrens osservò la devitrificazione della massa terrosa della porcellana e notò che la parte cristallina era meno solubile nell'acido idrofluorico di quel che lo fosse il rimanente. A. Bunzli dichiarà che la porcellana conteneva cristalli di silicato d'allumina con basso contenuto di postassa o addirittura esenti. E. Hussak notò la form-

azione nella porcellana di aghi sottili che sembravano essere sillimanite ed ottenne anche i medesimi mediante prolungato riscaldamento di argilla a 1,400°. J. W. Mellor decrisse la presenza di sillimanite in varii tipi di stovillie incluse alcune che erano state riscaldate ad una temperatura non inferiore a 1,200°. La sillimanite è stata anche riscontrata in argille bruciate è miscele sintetiche da A. Zollner, M. Glasenapp, E. Plenske, A. S. Watts, A. A. Klein è molti altri. E'interessante notare che J. W. Mellor è A. Heath osservarono che i cristalli si formavano in grande abbondanza con una miscela di caolino è felspato bruciati in un formo da stovillie ad una temperatura inferiore a 1,200°C. La sillimanite ottenuta in tal modo è stata separata dal rimanente del materiale mediante acido idrofluorico e le analisi mostrano che la composizione concorda approssimatamente con quella del minerale naturale. La seguente tabella dà i risultati ottenuti da diversi osservatori.

PROPORZIONE MOLECOLARE FRA SILICE ED ALLUMINA NELLA SILLIMANITE ARTIFICIALE.

Osservatore	Minerale Naturale	Mellor	Zöllner	Mellor e Scott		
				Caolinite	Ka + Al_2O_3	Argilla refrattaria
Silice ..	1·00	1·00	1·00	1·00	1·00	1·00
Allumina ..	1·00	1·03	1·02–1·11	1·13	1·13	1·06

5. *Formazione della "Keramite."*

Parecchi scrittori hanno ripostato che la sillimanite ottenuta mediante il riscaldamento dell'argilla refrattaria aveva dato la stessa composizione del minerale naturale. W. Vernadsky[12] trovo che vi era più allumina di quel che fosse richiesto per la relazione di unine molecolare mentre A. H. Cox ha riportato che allorche un pezzo di argilla refrattaria di Stourbridge vien riscaldata ad una temperatura di circa 1,700° la forma del composto insolubile in acido idrofluorico freddo è : $11Al_2O_3.8SiO_2$. Potrebbe farsi notare che H. St. C. Deville e H. Caron trovarono un simile composto mediante l'azione del fluoruro di allumina è silice. Recentemente noi abbiamo esaminato caolino è miscele di caolino ed allumina riscaldati a varie temperature fra 1,200° e 1,700° ed abbiamo trovato che il residuo insolubile lasciato dopo il trattamento con l'acido idrofluorico ha la composizione della sillimanite a temperature più basse, ma dopo riscaldamento a 1,700° la composizione tende ad avvicinarsi a : $3Al_2O_3.2SiO_2$. I dati sono esposti nella seguen te tabella.

PROPORZIONE MOLECOLARE FRA SILICE ED ALLUMINA NELLA "KERAMITE", ETC.

	1200°	1500°	1700°
Silice	1·00	1·00	1·00
Allumina	1·09	1·47	1·55

I risultati finora ottenuti fanno in certo modo supporre l'esistenza di una soluzione solida fra le due composti $Al_2O_3.SiO_2$ è $3Al_2O_3.2SiO_2$.

Le curve dei punti di raffreddamento del sistema binario allumina silice, quali determinate da E. S. Shepheard è G. A. Rankin mostrano che la sillimanite è stabile in contatto con la miscela ed è l'unico composto di questi due ossidi che si forma. Però la recente rideterminazione, per opera di N. L. Bowen è Grieg (non ancora pubblicata) delle curve dei punti di raffreddamento mostra che a temperature al disopra di 1,400° la forma stabile è : $3Al_2O_3.2SiO_2$ è non v'è sul diagramma menzione alcuna del composto che corrisponde alla sillimanite naturale. Questo contraddice i risultati ottenuti da Shearer è discussi nella prossima memoria. Shearer ha trovato che la radioscopia della caolinite che è stata calcinata a 1,700° mostra le linee che sono ottenute con sillimanite naturale, donde è possibile supporre che questo prodotto riscaldato contenga della sillimanite naturale. Risultati identici sono ottenuti con una miscela di una molecola di caolinite ed una di allumina ri scaldate alla stessa temperatura. La radiografia di una miscela di una molecola di caolinite è due molecole di allumina mostra però la presenza di un composto interamente nuovo di bassa simmetria cristallina ed è molto probabile che questo corrisponda a $3Al_2O_3.2SiO_2$, poiche questa è la composizione della miscela. Dai risultati che sono stati finora ottenuti sembra probabile che nelle condizioni che prevalgono allorchè le argille refrattarie sono riscaldate ad una temperatura di 1,700° la sillimanite è il principale composto che vien formato, ma in moltissimi casi trovasi anche prenente una certa quantità del composto $3Al_2O_3.2SiO_2$. In circostanze speciali sembra che il composto $3Al_2O_3.2SiO_2$ si sviluppi. Può notarsi che in tutti i casi anche quando v'è un eccese so di silice le radiografie di Shearer hanno mostrata la presenza di allumina libera in tutti i composti esaminati. L'esatta natura dei composti formati deve formare oggetto di materia per lo studio futuro.

Sarebbe conveniente dare all'ultima sostanza un nome e noi perciò suggeriamo quello di "Keramite." Per coloro che sono amanti di formule di costituzione abbiamo le seguenti per la sillimanite e la keramite.

SOMMARIO.

Le conclusioni alle quali si è giunti in questa memoria sono le seguenti :—

1. La disidratazione della caolinite non aviene ad una temperatura fissa ed è completa poco piùin su di 500°.
2. La caolinite allorchè vien riscaldata a poco oltre 500°C. si decompone in silice libera, allumina libera ed acqua.
3. Il punto critico in prossimità di 900°C. è in rapporto con una trasformazione della forma dell'allumina.
4. La sillimanite avente la stessa composizione del minerale naturale può svilupparsi a temperature al disotto di 1,200° è probabilmente sviluppa, al disopra di tale temperatura, soluzioni solide con $3Al_2O_3.2SiO_2$.
5. Un nuovo composto tende a formarsi a 1,700°, la cui composizione è $3Al_2O_3.2SiO_2$.

XXVIII.—The Dehydration of Kaolinite.

By J. V. Samoiloff.

THE dehydration of kaolinite has been studied by me in detail on a completely homogeneous, well crystallised material, namely, on the nacrite from the village of Saytzevo, in the Donetz basin. The results of my investigations appeared in Russian in 1909[1], and the dehydration heating curves, obtained during these investigations, were adduced later in the paper by Tammann and Pape[2].

My investigations did not indicate any difference in the properties of the two molecules of the kaolinite water, and my experiments furnish no confirmation of the view expressed by Prof. W. Vernadsky on this subject[3].

With regard to the substance obtained after the dehydration of kaolinite, I made numerous heating experiments, which were described in my paper: "On the Chemical Constitution of Kaolinite.[4]"

In my opinion, this question, especially in its first stage, is most easily solved by the application of the heating method. The chemical analysis encounters serious difficulties in this case, owing to the fact that the compound obtained by the dehydration of kaolinite may be represented by some unknown polymorphic modification, and may have, therefore, chemical properties of an unknown character.

In the course of my investigations, the technical side of which I described in detail, I obtained, by means of a self-recording apparatus, a series of characteristic heating curves for different minerals,—kaolinite, opal, diaspore, bauxite, hydrargillite, allophane andalusite, disthene, sillimanite, etc. I also obtained heating curves of pure compounds specially prepared for the purpose,—Al_2O_3 hydrate, etc.

The investigation of all these heating curves brought me to the conclusion that, in the process of dehydration, kaolinite is decomposed into two different compounds—not silica and alumina, but Al_2SiO_5 and SiO_2. The characteristic exothermal reaction, taking place at about 900°, is due to the molecular rearrangement of Al_2SiO_5.

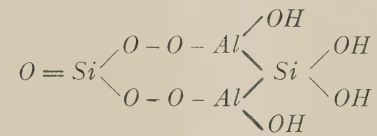
It is important to note, that allophane—a beautiful material from the Riasan Province, having the ratio $Al_2O_3 : SiO_2 = 1 : 1{\cdot}03$—displays the same exothermal reaction at 900° as kaolinite.[5] My assumption, therefore, that such compounds as kaolinite and allophane give rise, on dehydration, to Al_2SiO_5 in an identical modification, must be regarded as fully acceptable.

In accordance with the results of my experimental work, I cannot subscribe to the assertion of Prof. W. Vernadsky concerning the formation of $Al_2Si_2O_7$ by the dehydration of kaolinite.

The mode of distribution in the earth's crust of different modifications of Al_2SiO_5 on the one part, and of corundum on the other, is, according to geological data, fully in harmony with my hypothesis concerning the decomposition of kaolinite into Al_2SiO_5 and SiO_2. On the other hand, the formation of a substance with the formula $Al_2Si_2O_7$, suggested by Prof. W. Vernadsky, might give rise to many perplexing questions from the geological point of view.

The results of my investigation of the heating curve of kaolinite lead me to the conclusion that,—as in the case of the two molecules of kaolinite water, each of which, according to chemical experiments, has a particular character,—each of the two silica molecules of kaolinite stands in a peculiar relation to alumina; one of these molecules is more closely attached to alumina and remains in the group Al_2SiO_5, whilst the other is more feebly combined with it and is liable to be set free in the form of SiO_2.

In view of these considerations the constitutional formula, attributed to kaolinite by Prof. W. Vernadsky, must be somewhat modified, at the expense of its attractive simplicity. I should propose to replace it by the formula:



Even if we agree,—which I do not—with the views of Prof. W. Vernadsky relative to the mode of decomposition of kaolinite, we shall be bound to accept a modification of his constitutional formula for kaolinite, in view of the subsequent changes of $Al_2Si_2O_7$.

1 J. V. Samoiloff. On Kaolinite Water. *Bull. de l'Acad. des Sciences de la Russie*, 1909, p. 1137 (*Russ.*)

2 G. Tammanu and W. Pape. Silikatstudien I. Ueber den Wasserverlust des Kaolins, etc. *Zeit. anorg. u. allgem Chemie*, **127**, 45, 1923.

3 TRANS., **22**, 398, 1923.

4 J. V. Samoiloff, *Bull. de l'Acad. des Sciences de la Russie*, 1914, p. 779 (*Russian*).

5 J. V. Samoiloff. On the allophane from the Riasan Province, and on the adsorption minerals. *Bull. de l'Acad. des Sciences de la Russie*, 1915, p. 197.

XXIX.—Ventilation.

By E. R. Ludlow.

WHEN Dr. Mellor asked me to read a paper before your Society on Ventilation, I told him that I was uncertain as to being able to prepare a paper of sufficient length to occupy the amount of time usually devoted to a paper at these meetings. But, when I had carefully considered the subject, I found that I was quite wrong, and that I must devote my paper to probably one branch only of the whole subject. I therefore decided to speak principally on "Natural Ventilation," commencing with a few general remarks, then considering briefly the historical side of ventilation, next passing to the Theory of Ventilation, and finally discussing some practical applications which may be of interest to anyone connected with the Potting Industry.

There are numerous problems for the ventilating engineer in modern life and industry, and the amount of elaboration which has entered into the installation of ventilating schemes is bewildering to the uninitiated. To mention only one branch—the ventilation of places of amusement such as picture palaces. We have schemes installed whereby the air may be warmed in winter, cooled in summer, perfumed, washed, and one might even say, its hair parted down the middle. Then in the ventilation of public buildings there is a great diversity of opinion. For example, in the County of Stafford, in all recent schools, the cross ventilation system is in vogue. This, as will be known, consists of windows on both sides of the class room being made to open and allow the air to blow straight across the room, the theory being that the vitiated air is extracted and its place taken by fresh air. It is interesting to hear what one authority says about this idea :—

"When mechanical ventilation ceased to be employed in schools—apparently banned by the Board of Education—there was adopted in many schools a very primitive form of natural ventilation, consisting of adjustable openings in the upper parts of the windows, through which the wind entered and descended upon the unprotected bodies of the children underneath." "Glass hoppers in the lower parts of the windows may safely be used for the admission of air, where provision is made at the upper parts of the room for the effective extraction of the ventilated air, which naturally ascends to the higher levels from whence it should be withdrawn, and not returned by downward cross-currents to be rebreathed, as invariably happens when such provision is not made for its extraction." (*Unhealthy Schools*).

In the neighbouring County of Warwickshire, the Education Authorities for many years adopted what is known as the Plenum System. In this scheme the air is drawn in mechanically, passed through a washing apparatus, then warmed to a given temperature

and delivered into the room at, or near, ceiling level, and is finally extracted near the floor. This is of course, diametrically opposed to the laws of nature. Another authority criticises this method as follows :—

"To warm the air supply artificially is to reduce its invigorating and wholesome qualities....."

"If air was previously warmed, it would lose a portion of its oxygen, and if we got air short of oxygen, we had to breathe a greater number of times to supply the required amount, and that meant more effort."—(Professor Corfield, late Professor of Hygiene and Public Health, University College, London).

I believe that the Birmingham Technical School is reverting to the admission of fresh air through the windows and cutting out altogether the warming and washing of the air before introduction. One wonders how this diversity of theory and practice has arisen to such a marked degree. Is it possibly the inventor or manufacturer (usually one and the same person) who devises something "different from anything else," and by his eloquence persuades the Architect or Committee to try out his scheme? If it were possible to have a definition of, say, efficient Natural Ventilation, and efficient Mechanical Ventilation, it would be to the ultimate good of the community ; but where shall we go to find a sufficiently high authority on the subject, and, incidentally, one who will study the financial side of the question?

The ordinary procedure, when a new building is to be erected, is, that the preparation of the plans and details is placed in the hands of the architect and quantity surveyor. They probably consult various experts for specialities, in which may be included ventilation. Now the Firm they consult have their own special manufactures and patents and, naturally, put these forward, backed up with strong arguments and figures ; so that we may easily get two buildings of a similar character erected side by side, both fitted up with ventilation schemes diametrically opposed to each other in theory and practice. Illustrating this point, I recently inspected a picture palace just outside the Birmingham boundary. The ventilating scheme was a farce and probably cost ten pounds to install. If that building had been erected a quarter of a mile away, and inside the Birmingham boundary, the Licensing Justices would have insisted on a scheme to change the air every 15 mins., at a probable cost of £200. Unfortunately from an efficiency standpoint, the deciding factor is usually "the cost." It is distinctly unfortunate that an installation of vital importance should frequently have to be omitted on such grounds. Of course, recent legislation has enforced efficient installations in factories, to the satisfaction of the Factory Inspector. There is a Bill before the House of Commons now, dealing with the Regulation of Offices, in which ventilation is specially mentioned ; the wording, however, is somewhat indefinite—"It must be ventilated in a sufficient

manner." Here again we shall be up against the difficulty of definition.

It is not the object of my paper to dwell on these points, but it is of interest to note them in passing. I should like now to consider the elementary principles of Ventilation, and to commence by asking: "What is Ventilation?." The dictionary gives—"The act of ventilating, and the replacement of vitiated air by pure, fresh air." What is vitiated air? From the dictionary we get—"Vitiate—to render faulty or imperfect. To injure the quality or substance." Let us examine what we human beings do to pure air to make it faulty or imperfect. Pure air is composed of oxygen and nitrogen, not chemically united, but in a condition of mechanical mixture. The proportion of these two gases is approximately 20·9 per cent. of Oxygen and 79·1 per cent. Nitrogen, measured by volume, or if measured by weight 23 parts of Oxygen to 77 parts of Nitrogen. A cubic foot of air at freezing point, at a pressure of 30 inches of mercury, weighs $566\frac{3}{4}$ grains, the respective weights being—Nitrogen $436\frac{1}{2}$ grains and Oxygen $130\frac{1}{4}$ grains. At a temperature of 80 degrees, a cubic foot of air weighs only $516\frac{1}{4}$ grains, composed of nitrogen $397\frac{1}{2}$ grains and oxygen $118\frac{3}{4}$ grains. Therefore, if a person breathes every four seconds when the temperature is 32 degrees to obtain sufficient oxygen, he must breathe much quicker at a higher temperature to get a similar amount, and, therefore, requires more air. In addition to nitrogen and oxygen, pure air contains four parts of carbonic acid gas in ten thousand. There is also a watery vapour constantly present in the air, and the warmer the air, the greater the amount of watery vapour contained therein.

In further examination of these gases, oxygen is colourless, tasteless and has no smell. It is the most abundant of all the elements in nature and unites with almost any substance. If the supply of oxygen in the air is diminished, life becomes gradually feebler. The nitrogen in the atmosphere is also without colour, taste or smell, and its function is to dilute the oxygen. When we enter a room which is full of pure air, the atmosphere will be naturally perfect and mechanically pure. As soon as we begin to breathe the air in the room, we begin the process of vitiation. We remove oxygen from the atmosphere, and add to it CO_2 and also various animal products emitted from the lungs. The watery vapour is also increased. The added quantity of CO_2 to the atmosphere becomes dangerous according to the amount generated. When the atmosphere contains 8 parts it is "rather close"; $10\frac{1}{3}$ parts —"close." $12\frac{1}{2}$ parts—"extremely close."

The bodily organ, which conveys to the mind that the atmosphere is bad, is usually the nose, but not invariably so. A person suffering with a weak heart entering a room containing a high percentage of CO_2, would probably experience difficulty in breathing, as a result of lack of oxygen in the air. It is a strange fact that

persons can become accustomed to impure air in a room, within certain limits, fairly quickly, but if one leaves the room and walks into the outside air and returns again, it would be very quickly apparent that the atmosphere of the room was bad. In order to illustrate, by occular demonstration, what changes actually take place in the atmosphere of a sealed room occupied by human beings or animals, a model such as that illustrated in Fig. 1 may be

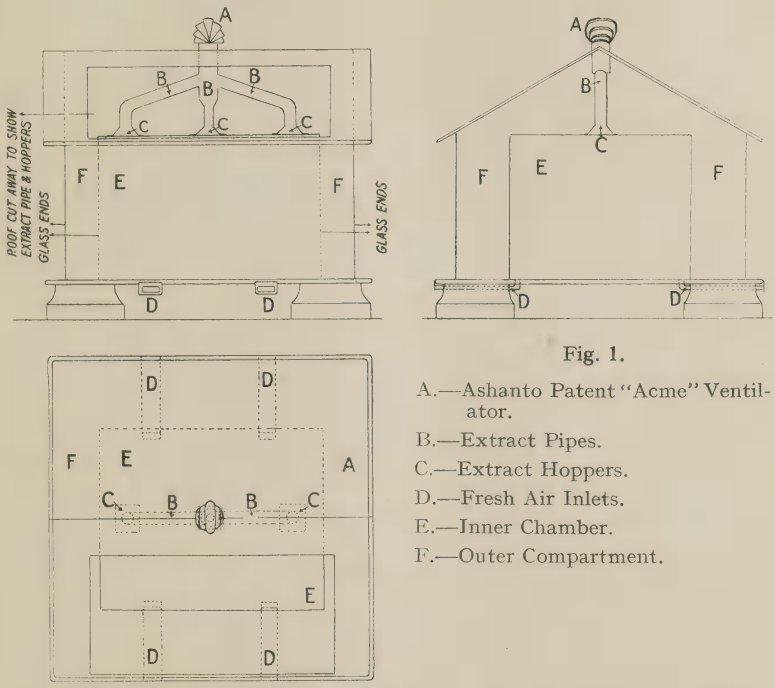


Fig. 1.

A.—Ashanto Patent "Acme" Ventilator.

B.—Extract Pipes.

C.—Extract Hoppers.

D.—Fresh Air Inlets.

E.—Inner Chamber.

F.—Outer Compartment.

employed. It is estimated that one lighted parafin-wax candle will produce one half of the quanity of CO_2 produced by a man in the same length of time. The model illustrated has an inner chamber fitted with glass ends, and this inner compartment is fitted with air inlets and outlets. If these are all closed up, the chamber will be reasonably airtight, and if three lighted candles are then placed at varying heights in the chamber, it will be noticed that, although when first put inside they burn quite brightly, in the course of a minute or so the light will become perceptibly feebler. Drops of moisture will appear on the inner side of the glass, caused by the uniting of the hydrogen of the candle oil with the oxygen of the enclosed air. Now, the upper candle flame will die down first and the lower one will remain burning for a little time longer. The

meaning of this is, that the oxygen in the chamber has gradually been used up. The CO_2 generated ascends to the top of the chamber and pollutes the air where the top candle is burning and gradually puts the light out. The bottom candle still finds a little oxygen in the atmosphere in the bottom of the chamber but if left long enough it would also go out. If the inlets and outlets are now opened, in order to flush the chamber with air containing oxygen, the remaining candles will soon be burning as brightly as at first.

This experiment is, of course, greatly exaggerated in the dimensions of the chamber to the CO_2-producing capacity of the candles, but that is merely to show a quick result. If a human being were placed in a totally sealed room, life would gradually become feebler and flicker out like the candle flame.

Ventilation is a comparatively recent sanitary science. If we go back to the early days of the Roman occupation of Britain, we find in the traces of buildings which have been unearthed from time to time that the Romans evidently gave considerable attention to the ciruclation of air in their houses. There are two Roman remains in the Midlands which I have had the opportunity of visiting, one at Chedworth (in the Cotswold Hills) and the other at Uriconium, near Wellington, Salop. In both these buildings there are very interesting traces of the method adopted by the Romans for heating the living rooms, and we may reasonably assume that due attention was paid to the allied subject of ventilation.

The short descriptions given in the guide books are as follows :—

Chedworth. "In viewing one chamber, the attention of the visitor is especially directed to the system of heating by means of a series of flues, to which the term "Hypocaust," from the Greek, literally "to set on fire from below," has been applied. A few words as to its construction may be interesting.

The "Hypocaust," then, was simply a place where heat was generated for the supply of the adjoining rooms, it not being the practice among the Romans to use open fire places. Their rooms, at least the principal ones, were usually floored with a tesselated pavement, which was arranged in a very ingenious manner to ensure warmth and dryness. The plan of proceeding was first to erect rows of small pillars, or pilae, upon which was laid a continuous floor of red brick slabs. On this suspension was spread a stratum of concrete, composed of pounded bricks and lime, laid to a regular thickness of about six inches, and this, when dry, formed the bed on which the tesselated pattern was worked. It will be noticed that the heated air passed between the pilae beneath the floor, and by modifying the arrangement the amount of heat could be regulated. It has often been a question as to what became of the smoke. According to Pliny, it was carried on to the wood-house, and used for drying the fagots."

Uriconium. "The Roman system of heating buildings was like that in use at the present day, viz., by hot air, but was unlike

our method, which employs metal pipes through which the heated air passes, sunk in trenches in the floors, covered by gratings, or placed along the walls. Instead of this, in Roman times, little columns, usually of brick, set very close together, were erected on a firm floor of cement, and on the top of these columns was laid another floor from 5 inches to 1 foot thick, so that there was a space between the two floors, called a hypocaust, which varied in height according to circumstances. In these baths at Uriconium, the little columns which supported the upper floor were more than three feet high. A small opening in the outer wall of the chambers allowed of the introduction of fuel, which, when lighted, and continually fed from without, filled all this space beneath the upper floor with flame and heat. Nor was this all; flue pipes, communicating with this heating chamber ran up the walls, and the heat radiated from these pipes warmed the room. The flue pipes were sunk in the walls and plastered over, so that they could only be detected by the warmth spread around. In rooms which had to be extra heated the whole surface of the walls was lined by pipes, the heat being given out from the entire wall faces."

From the end of the Roman occupation and up to comparatively recent times, there appears to have been little or no enlightenment as to the benefits of fresh air. Coming down to later days, it will be remembered that the Window Tax was imposed in 1695 and again at a later date for special revenue purposes. As late as 1850 the sum of £1,832,684 was obtained through this tax, which was repealed in 1851. The injurious results to health, from the exclusion of light and fresh air from living rooms cannot be estimated, but it undoubtedly fostered disease and took a large toll of human life and happiness.

We now come to consider what is Natural Ventilation, or in other words—Ventilation by way of the Laws of Nature. If we can discover natural laws and work with them, we are sure of success. If we try to work against them, we are fairly sure of failure. It is, of course, well known that warm air rises, and cold air falls. When a number of people are occupying a room, each person who is warmer than the surrounding air, naturally warms the temperature locally, and thereby causes an upward current. As the air gets warmer, it expands and thereby creates movement. It is essential that, if we are to get adequate natural ventilation, we should arrange to extract the vitiated air from the top of the room, and admit fresh cool air at a lower level. We must, therefore, place a vertical ventilating shaft or shafts from a central position in the ceiling, going through the roof at its highest point, and terminating in the outside air; we must also arrange a series of fresh air inlets in suitable positions, so that we get complete circulation of air. We shall find that the expansion caused by the warm air will move it in an upward direction, and will cause a varying amount of velocity in the shaft, which we have provided

as an outlet. Obviously, the warmer the air becomes, the greater the velocity we shall get. If we place a sheet metal air shaft over an electric heater, we find that the warm air rising will give us in this instance an upward velocity of 150 ft. per minute. This can be shown by an anemometer placed over the mouth of the shaft. Our next step is to endeavour to increase the velocity by some means, and thereby improve the circulation of air in the room.

It is a law of nature that, if a column of ascending air meets a current of wind at a certain angle, a greatly increased velocity is obtained. This is only true under certain conditions. If the outside current of air should be travelling in a downward direction instead of increasing the upward velocity in the shaft, we get exactly the opposite result, that is a down-draught. Also our open shaft would allow rain or snow to travel down it. We must protect the air shaft from both down-draught and the elements. To accomplish this desirable result, many weird and wonderful inventions have been brought into being; probably hundreds of attempts have been made, but very few have come through the experimental stages successfully.

It is to be remembered that due regard must be paid to appearance. No architect is willing to have the elevation of his building spoiled by an unsightly ventilator placed on the main roof, and it not infrequently happens that he will omit the scheme of ventilation altogether, rather than spoil the appearance of his building. It is a problem of the ventilating engineer frequently to design an apparatus which is invisible above the ridge line—usually at the expense of efficiency. It is first of all vital that we do not retard the velocity of our up-cast in any way, and that we must make ample allowance for dealing with volume as well as velocity. The following illustrations (Figs. 2—9) show some standard designs of ventilators.

Fig. 2.

Fig. 2 shows a cone covering a vertical shaft, designed with the purpose of protecting the open pipe from rain or snow and directing the air horizontally across the open shaft. This type creates a back pressure under certain conditions and the centre of the cone will act as a baffle, thereby giving, at times, a down draught instead of an uptake.

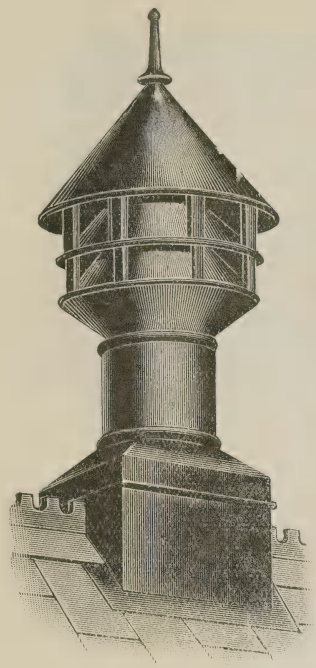


Fig 3.

Fig. 3. This is of similar construction, but introduces another cone. This increases the efficient area, but does not obviate the tendency to back pressure.

Fig. 4. This ventilator is built up on the cone principle worked to a square external with a circular internal shaft.

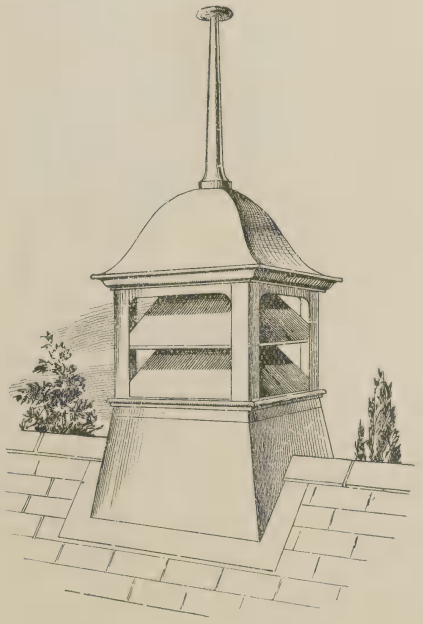


Fig 4.

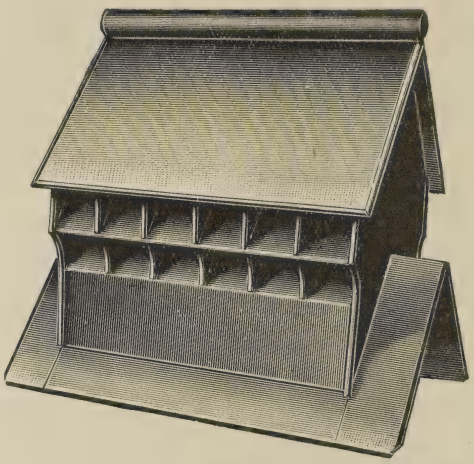


Fig. 5.

Fig. 5. Another louvres type of ventilator consisting of rows of louvres with openings on two sides. This ventilator will act well when a wind blows straight through it, but is obviously handicapped when the wind strikes on either end. One of its chief merits is neatness of construction from an architectural standpoint.

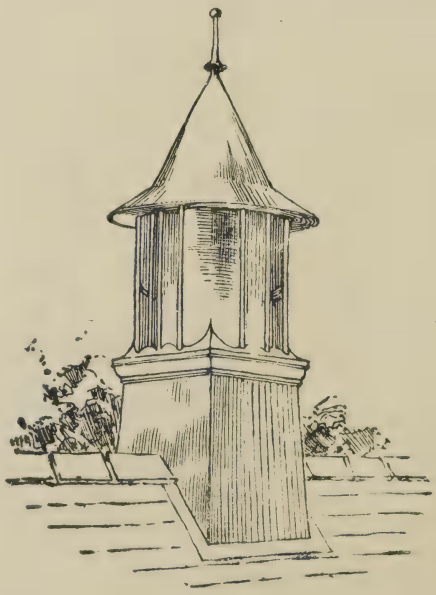


Fig. 6.

Fig. 6. The plan of this design shows the arrangement of the louvres in the vertical type of extractor, in which a partial vacuum is set up. The wind then passes out on the opposite side and induces velocity of air. It requires a fairly strong current of wind to force its way through the louvres and is somewhat inoperative in light winds.

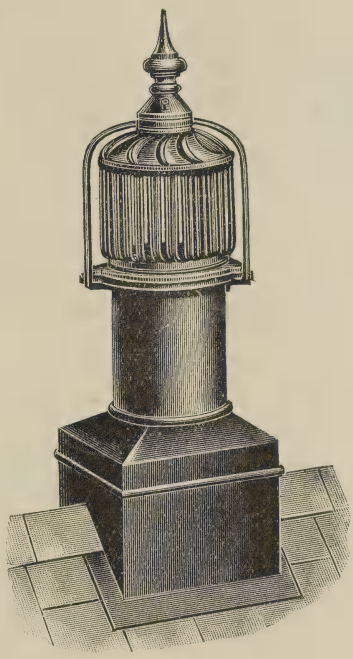


Fig 7.

Fig. 7. This is an old type of ventilator which was greatly favoured before it was realized that it is not necessary for the head of a ventilator to revolve with the wind in order to set up an exhaust action. A real objection to this is that it readily gets out of order, must be oiled periodically and to its being made from light material to enable it to swing round with the wind. Hence its life is fairly short.

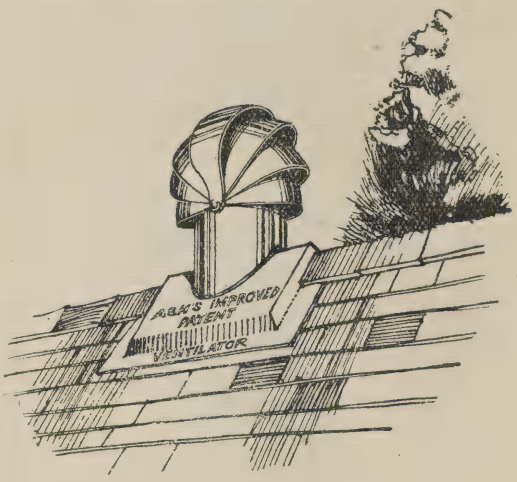


Fig. 8.

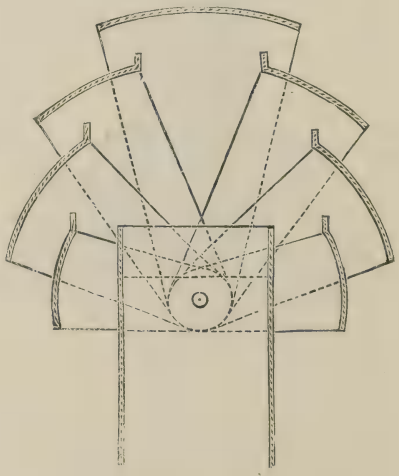


Fig 9

Figs. 8 and 9 show the "Ashanco" Patent, "Acme" type. This ventilator is arranged with a series of hollowed-up louvres, so that the wind striking from any angle is conducted across the open pipe. There are no sharp angles and, consequently, friction is reduced to a minimum. The area inside the head equals at least twice the area of the vertical shaft, thus allowing a gathering chamber for the vitiated air which is readily dispersed by the outside wind.

TABLE I.

Type	"Ashanco" Patent	Fig. 3	Fig. 6	Fig. 2	Fig. 5
Actual reading	3000	1760	1649	1590	1570
Efficiency (per cent.)	100	58·7	55·0	53·0	52·3

Table I. indicates the efficiency of some of these ventilators. The figures were obtained by a long series of anemometer tests under exactly similar conditions. A special base was erected on the roof at our works, and each ventilator was constructed with the same size shaft and box, so that we could take one ventilator off and put another one on without any waiting. By so doing, each extractor had practically the same conditions of temperature and wind pressure to act upon it.

Natural ventilation, as applied to the Pottery Industry, especially with regard to Drying Stoves, etc.

From the foregoing remarks it is obvious that the higher the temperature in the room, the greater the velocity of the air will be in the exhaust shaft ; we therefore have the opportunity of working with the assistance of nature if we pay due regard to the following points :—

1. Extracting (*a*) from the highest point in the room, and (*b*) with due regard to the position of inlets for fresh air.
2. Inlet ventilators to be as low as possible and at as many points as possible in the room.

We shall then get a good circulation of air which will remove from the stove and other rooms the moisture which is detrimental to quick and uniform drying. I assume that the average Potter's Stove is used more especially for drying at night. The stove is filled up during the day with green ware, but the constant opening of the doors which takes place while the ware is being carried into the stove allows a certain change of air to take place, thereby removing a certain amount of dampness. This damp air will, of course, come into the work shop and be inhaled by the workers if there is no means of extract into the outside atmosphere. When the stove is closed up for the night the process of drying must be considerably retarded by the condensation of moisture which takes place if no suitable outlet is provided.

If we have installed a suitable natural ventilation scheme, the consistent change of air will be in progress throughout the whole of the night drying period. When recently inspecting an installation of natural ventilators of the "Acme" type for ventilation of a saggar drying house, the charge hand gave me his opinion that he estimated that they were drying as much in 4 days as previously took 7 days, and that there was a distinct improvement in the ring

of the ware. It may be said that a loss of heat will result by having a constant change of air in the stove, but it is quite reasonable to assume that even a slightly lower temperature plus drawing out of damp air, will give better results.

I recently inspected a saggar drying house where the manager informed me that the conditions were very bad, there being no circulation of air and a great deal of humidity. This gentleman, who was a native of the district, said to me: "When my old mother wanted to dry clothes, if there was no wind she said 'It isn't a washing day,' and, he added "that is the fault down here. I want a washing day in my saggar house." This particular room was a basement, and I found working on one side of the room a large propeller fan about 36″ diameter, capable of changing the air in the room 20 times per hour if properly arranged; but, despite this constantly running fan, there was no movement of air at all in the main portion of the room. The reason for this was that on the same wall as the fan was fixed, there was a large shaft opening to the outside air, within a few feet of the fan. This opening was of sufficient size to feed the extract fan with all the air it needed and, consequently, there was a complete short-circuit. This will illustrate my point, that any scheme of extract ventilation must be carefully thought out and so arranged as not to short-circuit. You may get a very high velocity and volume of extraction in a mechanical scheme, but unless the whole of the air in the building comes under the benefit of the installation it is useless.

In a recent inspection of a series of drying stoves which were connected up by means of a number of shafts to one central fan discharging horizontally, I found that there was a discharge in the mouth of the shaft equivalent to 17 changes per hour of the air in each stove, but as the point of extraction in each case was immediately over the door into the shop, and no other inlet was provided, there was again a complete short-circuit, and the air at the back of the stove was stagnant. The result must be in this case that the ware placed in the stove for drying comes out very unevenly dried, as the ware placed near the door would dry much quicker than would be the case at the back of the stove. In a properly installed natural ventilation scheme we get certain obvious advantages:—

1. The scheme works 24 hours per day and 7 days per week.
2. There is no cost of maintenance.
3. There is no possibility of a breakdown, which is inevitable in the case where the motor, which is working a mechanical scheme, fails.

During the last two years I have had the opportunity of observing and taking tests of actual installations of natural ventilation, and after carefully studying the data obtained it is evident that the relation of the temperature to the size of the ventilator used is of importance. If we start out with a table of figures,

such as any ventilating engineer uses for giving average capacity of, say, a 12″-diameter shaft, which figures have been arrived at by a test on a class room or office where the temperature is normally about 60°, we shall be a long way out of our reckoning when we are dealing with a potters' stove at 90° or 100° or a saggar shop at 110° or 120°.

It is therefore advisable to obtain the opinion of one who has made investigations on these points, and can advise, with a reasonable degree of certainty, as to the result to be expected from a natural scheme.

In conclusion, I would like to demonstrate the action of a natural ventilation system in a building such as a potters' drying stove. The model previously referred to (Fig. 1.) is typical of the construction of many potting shops in the district; a room open on two sides to the outside air with the stove in the middle of the shop. It will be observed that the stove and the shop have fresh air inlets arranged on two sides at a low level and that there is an arrangement of ducting, comprising main and branch pipes, from the ceiling of the stove connecting to an air extractor of the Acme type on the ridge. If a piece of lighted paraffin rag is placed in the inner chamber to generate smoke, it will first be noted that the smoke hangs about heavily when no ventilating apparatus is working. But on opening up the inlets and outlets, and directing a current of air on to the "Acme" ventilator, the velocity of the air currents is greatly increased, and in a short time the chamber is entirely freed from smoke. It must be remembered, in this simple demonstration, that the air in the inner chamber is not heated up to anything like the temperature existing in a drying stove; if that were done, a much greater velocity would be obtained.

DISCUSSION.

Major B. J. Moore:—I am sure we have all been extremely interested in Mr. Ludlow's lecture, which has brought up some points which will give us food for thought, and, perhaps, help us to put our houses in order, so to speak. It seems to me that, in regard to this question of ventilation we, in the pottery trade, have two things to consider. One is the question of potters' stoves or drying stoves, and the other is the natural or artificial ventilation of our workshops. Leaving out for the moment the question of potters' stoves, which has been dealt with by Mr. Ludlow so thoroughly, I, personally, am of the opinion that the "Plenum" system of heating is the most satisfactory that we have yet had put before us. I say this not because I consider it to be an ideal system of ventilation, but because in studying ventilation from a pottery point of view, it seems to me to be so intermingled with shop temperature, draught and humidity, that we must have some system that is more or less foolproof. The average pottery worker is very susceptible to draughts and to variations of tem-

perature of any sort, and if we had a system whereby we could keep a constant temperature range in the neighbourhood of about 70 degs. F., and conld reach that temperature quickly and at the same time ensure a change of atmosphere from 4 to 6 times in the hour, I think we should have arrived at something as near foolproof as we could hope to get it.

At our works we have recently constructed a large three-story building and introduced the system to which I have referred. I do not know that it was anybody's particular patent, but the principle of the thing consists in sucking in air by means of a big fan, blowing it over hot radiators and then introducing it into the workshop in definite quantities. Personally, I fail to understand Prof. Corfield's criticism of this system, in which he says that it is no good because it extracts oxygen from the air. If you are merely sucking in air from the outside, blowing it over radiators and passing it on into a room, I myself, cannot quite see where the oxygen in the air goes to. But I should like to have Mr. Ludlow's opinion on this point.

Mr. E. A. R. Werner:—As this is essentially a pottery gathering, I should like to comment on the dictum that extraction, to be really consistent with the laws of Nature must, of necessity, be carried out in an upward direction. This may be an ideal to aim at in atmospheres which are not vitiated in any way except by the products of respiration, gas flames, or similar impurities which are not heavier than air. But in many of our processes in the Potteries, as well as in certain other industries, we have to deal with impurities which are definitely heavier than air; these include most of the dusts we have to contend with in the Potteries, and particularly the very fine invisible particles of lead dust in the lead departments; until it is demonstrated to the contrary, we are inclined to feel that the right way to deal with dusts which are heavier than air is the same as the successful method of dealing with fumes which are heavier than air in the doping rooms of aeroplane factories, that is to say, by extraction fans at the floor level or as near the floor level as we can get them, in order that the relatively heavier fumes and dusts may, in no circumstances, be drawn up past the workers' breathing level.

Another question arises in connection with the heating methods advocated by many architects for the modern, single-floor, saw-toothed buildings. I refer to the method of heating by means of pipes arranged close under the skylights, which is, obviously, the place where the building is most cooled by severe temperatures outside the glass. Although this problem possibly does not closely affect us here, there is no doubt that it is becoming a very real problem in places as near to us as Leek, where many such buildings are being introduced; if you do not feel, Mr. Chair-

man, that it is irrelevant, I should like to hear what Mr. Ludlow would advocate as the right principle to adopt in these places.

Mr. Ludlow appears, also, to differ from certain other experts, when he states that the "closeness" of a room is more or less directly proportional to the percentage of carbon dioxide in the air. Mr. Ludlow expresses the hope that someday in the near future, we may have a sort of ventilation thermometer, by which we shall be able to read off straight away the proportion of CO_2 in the room. Well, we already have, of course, certain forms of apparatus which very nearly approach to that degree of efficiency; but there is some doubt whether the proportion of CO_2 is, by itself, a sufficient test—at any rate, within the ranges with which Mr. Ludlow has been dealing.

Mr. Newman:—The question of ventilation, both of potters' shops and drying stoves, has, I am afraid, not been sufficiently taken into our consideration in the past, and, unfortunately, in many of our existing potteries we have inherited a legacy from the past, when the efficiency of the stove was governed only by first cost. Having had these stoves handed down to us, it is much more difficult now to ventilate them efficiently than it would have been if we had to start again right from the beginning.

Then again, there is another question which is coming to the fore to-day in connection with potters' stoves, and that is the conditions under which the drying must be carried out. Some people say we must try to remove the humidity as much as possible, whilst others contend, on the contrary, that we must keep the air at a certain humidity over a certain period. There is no doubt, however, that Mr. Ludlow's lecture to-night has given us considerable information in regard to natural draught, and I think his efficiency table was one of the most interesting items that he has put before us.

Unfortunately, with the ventilation of the workshops, whatever you may do for the benefit of the worker, the latter has usually got an ingrained idea of his own as to what efficiency is, and if you put in for him the nicest ventilation system you can possibly get, he will imagine that he is getting a draught. But give him a chance to open a window, and he will do so, and create a much more violent draught than your ventilation system would give. That is one of the things we have to contend with.

Then again, there is no doubt about it that with the potters' stove of to-day, it is a question as to whether natural draught can satisfactorily deal with the varying conditions of our English atmosphere. We have to maintain certain temperatures, and with the variable conditions outside it is quite a question as to whether natural draught, pure and simple, without some mechanical aid, is quite sufficient to enable us to deal satisfactorily with the problem.

I think it would be very interesting if we could carry this

matter a stage further in subsequent discussions, and in the hope that this may be done, I would very much like to thank Mr. Ludlow for the lead which he has given us to-night.

MR. LUDLOW:—In my introductory remarks, I mentioned that it was necessary to confine the subject of this paper to one aspect of Ventilation, namely, "*natural ventilation*." The points mentioned by Major Moore regarding "Plenum Heating," have not been dealt with in this evening's paper, and, of course, a whole lecture could be devoted to this subject. The "Plenum" system has many excellent points for specially designed buildings, but the principle of warming air artificially to a given temperature, before admitting it into the workshop, is a debatable point. I mentioned in my paper that air at 32° contains 130¼ grains of oxygen per cubic foot, and at 80°, only 118¾ grains of oxygen. The contention is, therefore, that fresh air is more invigorating to the worker than the pre-warmed air delivered through the medium of a mechanical scheme. This is what Professor Corfield points out in the extract I have given, and to which both Major Moore and Mr. Werner have referred.

The points raised by Mr. Werner regarding "heavier-than-air dusts and fumes" are again outside the scope of this paper. To deal with such problems, it is necessary to employ specially designed mechanical apparatus suitable to the conditions arising in each individual case.

Mr. Werner referred to the principle of warming the air by means of hot water pipes immediately below the glass portion of north light roofs. This system does not admit of any natural scheme of ventilation being employed, since if extract ventilators are introduced in their most efficient positions, *i.e.*, at the highest point of the building, they will draw out the warm air immediately beneath them.

Mr. Newman mentioned "an inheritance of a legacy of bad conditions existing in the older types of drying stoves in the Pottery districts." My later remarks and demonstrations have been made with a view to suggesting improvements in these local conditions. Many of the newer buildings in this district have been designed by clever architects in North Stafford, who have devised means of obviating many of the past imperfections, and in the course of time, as the area is rebuilt, these bad conditions will, doubtless, disappear. In a few years' time, it will not be necessary for anyone to come along, as I have done to-night, to speak specially on the ventilation of potters' stoves, etc., but in the meantime, I trust that the facts I have put before you may be of some service in trying to improve the ventilation of potters' workshops, and thus provide healthier conditions for the workers, and more efficient drying results.

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TRANSACTIONS

OF

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ABSTRACTS.

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1924.

INTRODUCTION.

THE following are abstracts from papers bearing upon the clay, refractories, and glass industries in the more important foreign journals as well as those of our own country. The abstracts are arranged roughly in eight main classes. The groups are constantly overlapping, and, to avoid repetition, a copious index is appended. This will enable any reference to be quickly found. Most of the journals quoted are permanently filed so that the full papers may usually be consulted by members of the Society. Full translations of any of the foreign papers can be obtained at a small charge. As a rule the abstractor indicates the "subject title" of those articles which, in his opinion, contain either no original matter, or matter not suitable for abstraction. These abstracts were made possible by a grant from the Joint Committee of Allied Pottery Manufacturers, and were compiled by Mr. F. SALT (with the exception of a few initialled).

The following particulars respecting patents may be of use to members:—

Country	Address	Cost
Britain ..	Patent Office, London	One Shilling (extra postage outside United Kingdom)
United States	Patent Office, Washington ..	Five cents
France ..	L'Imprimerie Nationale, 87, Rue Vielle du Temple, Paris	One franc
Germany ..	Patent Office, Berlin	
Austria ..	Buchhandlung Lehmann und Wenzel, Wien I, Kärntnerstrasse, 30	
Denmark ..	Patent Office, Copenhagen ..	One krone
Norway ..	Patent Office, Christiania ..	One krone
Sweden ..	Patent Office, Stockholm ..	One krone
Italy ..	— — Rome	Specifications not printed
Japan ..	— — Tokyo	Price not stated
Australia ..	Government Printer, Melbourne	One shilling

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In ordering a copy of a patent, the number of the patent and year of the patent, the name of the patentee and the subject of the invention should be stated.

Titles of Journals Abstracted, with Abbreviations.

Allg. Tonind. Ztg... "Allgemeine Tonindustrie Zeitung" (Czecho-Slovakia)
Amer. Min..... "American Mineralogist" (American)
Analyst..... "The Analyst" (British)
Ber. D. K. Ges. .. "Berichte der Deutschen Keramischen Gesellschaft" (German)
Brennstoff..... "Brennstoff-Chemie" (German)
Brick..... "Brick & Clay Record" (American)
Brick Pot. Tr. J..... "Brick & Pottery Trades Journal" (British)
Brit. Claywr..... "British Clayworker" (British)
Bull. Imp. Inst..... "Bulletin of the Imperial Institute" (British)
Can. Chem. Met..... "Canadian Chemistry & Metallurgy" (British)

Cement Eng. News..... "Cement & Engineering News" (American)
Cer..... "La Céramique" (French)
Cer. Ind..... "Ceramic Industry" (American)
Ceramist..... "The Ceramist" (American)
Cer. Vet..... "La Ceramica ed il Vetro" (Italian)
Cer. et Verr..... "La Céramique et la Verrerie" (French)
Chem. Age..... "Chemical Age" (British)
Chem. Met. Eng... "Chemical & Metallurgical Engineering" (American)
Chem. News..... "Chemical News" (British)
Chem. Tr. J. "Chemical Trade Journal & Chemical Engineer" (British)
Chim. Ind..... "Chimie et Industrie" (French)
China Rev..... "China Clay Trade Review" (British)
Claywr..... "Clayworker" (American)
Corr. Cer..... "Corriere dei Ceramisti" (Italian)
Deut. Töp. Zieg. Ztg. "Deutsche Töpfer und Ziegler-Zeitung" (German)
Diamant..... "Diamant und Glas-Industrie Zeitung" (German)
Econ. Geol..... "Economic Geology" (British)
Faenza..... "Faenza" (Italian)
Fenerfest..... "Fenerfest" (German)
Feuerung..... "Feuerungstechnik" (German)
Gas J..... "The Gas Journal" (British)
Gas World..... "Gas World" (British)
Gazz. Chim. Ital..... "Gazzetta Chimica Italiana" (Italian)
Giorn. Chim..... "Giornale di Chimica industriale ed applicata(Italian)
Glashütte..... "Glashütte" (German)
Glas-Ind..... "Die Glasindustrie" (German)
Glass..... "Glass" (British)
Glass Ind..... "The Glass Industry" (American)
Ind. Chim..... "L'Industrie Chimique" (French)
J. Amer. Cer. Soc. "Journal of the American Ceramic Society" (American)
J. Amer. Chem. Soc. "Journal of the American Chemical Society" (American)
J. Chem. Soc..... "Journal of the Chemical Society" (British)
J. Ind. Eng. Chem. "Journal of Industrial & Engineering Chemistry"(Amer.)
J. Soc. Chem. Ind. "Journal of the Society of Chemical Industry" (British)
J. Soc. Glass Tech. "Journal of the Society of Glass Technology" (British)
Kalk Schm.-Ztg..... "Kalk-, Gips-und Schamotte-Zeitung" (German)
Keramos..... "Keramos" (German)
Ker. Rund..... "Keramische Rundschau" (German)
Met. Erz..... "Metall und Erz" (German)
Min. Met..... "Mining and Metallurgy" (American)
Nature..... "Nature" (British)
Pat. J..... "The Illustrated Official Journal (Patents)" (British)
Porz. Glas..... "Die Porzellan und Glashandlung" (German)
Pot. Gaz..... "Pottery Gazette" (British)
Pot. Glass Rec..... "Pottery and Glass Record" (American)
Prod. Chim..... "La Revue des Produits Chimiques" (French)
Quarry.... "The Quarry & Surveyors' & Contractors' Journal (British)
Rev. Mat. Constr. Trav. Pub. "Revue des Matériaux de Construction et de Travaux Publics" .....(French)
Sprech..... "Sprechsaal" (German)
Südd. Tonind. ..... "Süddeutsche Tonindustrie" (German)
Tonind. Ztg..... "Tonindustrie Zeitung" (German)
Tonwar. Ofen Ztg..... "Tonwaren Ofen-und Töpfer-Zeitung" (German)
TRANS..... "Transactions of the Ceramic Society" (British)
Trans. Faraday Soc..... "Transactions of the Faraday Society" (British)
Verre..... "Le Verre" (Belgian)
Zprávy Ceskoslov. Keram. Spol. "Transactions of the Czechoslovakian Ceramic Society".....(Czecho-Slovakia)

*** The first number represents the number of the volume, the last the year of publication, and intermediate numbers the page or pages where the subject is discussed.

Abstracts.

I.—RAW MATERIALS:

RAW MATERIALS: OCCURRENCE, PREPARATION, ETC.

WHAT EFFECT HAS WARM WATER UPON THE WASHING PROCESS? (*Ker. Rund.*, **31**, 416, 1923). Warm water tends to accelerate the settling process. If a suspension of clay in cold water is allowed to stand in a warm place, settlement takes place much more rapidly than in the cold. Furthermore, the settling is much more complete; the supernatant liquid can be drawn off quite clear. The action of warm water is probably of a colloidal nature, though the decreased specific gravity due to the higher temperature may also play an important part. Temperatures of 80°C. and over may be applied, without risk of affecting the physical or chemical properties of the clays or bodies, provided that they do not contain pyrites. If the latter impurity is present, the action of the hot water leads to the formation of iron sulphates, which discolour the body. To counteract this, a small percentage (about 0·1 per cent. of the dry weight) of pure, slaked lime (calcined marble) should be added. An insoluble double salt is then formed, which does not affect the composition of the body. The use of hot water in the washing process may also increase the plasticity of the clay.

THE MAGNETIC SEPARATION OF IRON-BEARING MINERALS FROM CLAYS.—H. G. Schurecht (*J. Amer. Cer. Soc.*, **6**, 615, 1923). Part I. of a research on "Clay Sewer Pipe Manufacture." The purpose of the experiments was to remove the coarse, iron-bearing minerals from clays magnetically in order to prevent the formation of black blisters on the finished product. These minerals are grouped in decreasing order of magnetic susceptibility as follows:—magnesite, siderite, hematite, limonite, marcasite and pyrites. Samples of raw ground sewer pipe mixtures, screened through a 10-mesh sieve, were treated with a low intensity magnetic separator, and by two high intensity separators of different type. To test the claim that magnetic susceptibility is increased by roasting, similar experiments were conducted on the same clays after heating at a dull red heat. The results showed that most of the coarse, iron-bearing minerals can be removed by means of a high-intensity magnetic separator. Although the cost of this treatment on the roasted clay is too great, it is considered that the separation from the raw material is not prohibitive to plants sustaining large losses due to this defect. In some cases, it may not only improve the ware, but may even reduce the cost of manufacture also.

RUSSIAN DEPOSITS OF FULLER'S EARTH AND ALLIED SUBSTANCES.—A. E. Fersman (*Reports on Natural Productive Forces of Russia*, No. 1, 1916).

HALLOYSITE FROM COLORADO.—E. S. Larsen and E. T. Wherry (*J. Washington Acad. Sci.*, **7**, 178, 1917).

LEVERRIERITE FROM COLORADO.—E. S. Larsen and E. T. Wherry (*J. Washington Acad. Sci.*, **7**, 208, 1917).

INTUMESCENT KAOLINITE.—W. T. Schaller and R. K. Bailey (*J. Washington Acad. Sci.*, **6**, 67, 1916).

CARBONISED CLAY AS A REFRACTORY MATERIAL.—W. Smith (*Iron Age*, **111**, No. 12, 1923). A new product for furnace linings is fully described.

SILICA IN CANADA; ITS OCCURRENCE, EXPLOITATION AND USES.—(*Gas World*, **79**, 143, 1923). A short résumé of a report issued by the Canadian Department of Mines.

THE USES OF KAOLIN IN PHARMACEUTICAL CHEMISTRY.—(*Chem. Age* ; *China Clay Rev. Sect.*, **10**, 9, 1924).

ON THE USE OF CLAY FOR MAKING MOULDS, ETC., FOR FOUNDRIES.—A. E. Buch (*Südd. Tonind.*, **5**, 54, 1923). Hints are given respecting the general properties required in clays used in foundry practice as, for instance, for making crucibles for steel foundries.

OCCURRENCE OF CLAY.—T. J. Drakeley (*Brick Pot. Tr. J.*, **31**, 169, 1923). The article deals with the origin of clays, *e.g.*, the degradation of granite by weathering to form kaolinite, the production of kaolin by the action of volcanic acid gases (hydrofluoric), formation of residual and transported clays. Wheeler's classification of clays is given in an abbreviated form.

VALUATION OF STONE DEPOSITS.—J. H. Watkins (*Rock Prod.*, **26**, No. 5, 37, 1923).

THE PRINCIPLES OF HYDRAULIC SEPARATION.—E. Shaw (*Rock Prod.*, **26**, No. 5, 82, 1923).

THERMAL ANALYSIS AS A MEANS OF DETECTING KAOLINITE IN SOILS.—J. Matejka (*Chemické Listy*, **16**, 8, 1922). The presence of kaolinite can be determined from the dehydration curve, which for pure kaolinite shows a characteristic break at 570-580° and this is not essentially affected by the presence of orthoclase, calcite, muscovite, quartz and bauxite. Magnesite, however, must first be removed by HCl.

PHYSICAL AND CHEMICAL PROPERTIES, TESTING, ETC.

THE MEASUREMENT OF THE PLASTICITY OF CLAY SLIPS.—K. E. Wilson and F. P. Hall (*J. Amer. Cer. Soc.*, **5**, 916, 1923). Up to the present, no unit of plasticity has ever been defined, and there is no generally accepted method of measuring this property. Various indirect methods have been sugggested, but they all tend to erroneous conclusions. The present work was confined to a study of the properties of mixtures of clay and water in the casting, rather than in the moulding range. In the light of the results obtained, it is recommended that, instead of employing the vague term "plasticity," the properties of a given clay should be expressed, at least for casting purposes, in terms of (*a*) the water content required to give proper working consistency, and (*b*) the resistance of the resulting slip to small deforming forces, such as gravity. In the experiments, use is made of a modified Bingham plastometer, and the figures reported are : (1) the amount of water required to produce a slip of a specified mobility, and (2) the yield value of the slip thus obtained. The method is shown to be capable of giving quantitative figures for the yield values, at constant mobility, which correspond with the customary qualitative ideas of plasticity. The amount of water required to give constant mobility varies remarkably, and does not appear to bear any definite relationship to the usual classifications of plastic clays. It probably corresponds more or less with the drying shrinkage. Small amounts of acid or alkali have a negligible effect on the mobility of a clay slip, but a very pronounced effect on the yield value, the variations being greater than the difference between a non-plastic kaolin and a highly plastic ball-clay. This brings out the necessity of carefully controlling the hydrogen-ion content of the water used in slip-making. It is recommended that an attempt be made to agree upon standard dimensions for the capillary and the desirable mobility for various purposes, and that the plastometer then be used as a standard method of test in the ceramic industry.

THE INFLUENCE OF SOME FLUXES ON THE TRANSFORMATION OF QUARTZ.—N. Parravano and C. Rosselli del Turco (*Gaz. Chim. Ital.*, **53**, 249, 1923). A brief review of the literature of the subject is followed by the presentation of the results of experiments carried out with the object of determining those substances which, acting as fluxes, are capable of effecting the transformation of quartz in a manner best calculated to produce good

refractories. The tests were performed on an Italian quartzite from Grignasco, containing: 96·5%, SiO_2, 2·06% Al_2O_3, 0·80% CaO, traces of Fe_2O_3, loss on ignition 0·70%. In contrast with the methods adopted by previous investigators, who, in general, worked with materials of a fixed grain-size, the authors experimented with the ordinary quartzite-lime mixtures as prepared in the manufacture of refractories, care being taken to obtain a thorough distribution of the fluxing medium, the action of which was to be determined, throughout the mass. A large series (about 300) of samples was prepared by the process usually adopted in making Dinas bricks and differing from them only by the addition of various oxides in the proportion of 0·5, 1 and 1·5 per cent., apart from the usual 1·5 per cent. of lime. The following types of refractories were prepared: normal, (*i.e.*, without any special additions), with Fe_2O_3, with P_2O_5, with B_2O_3, with CaO, and with WO_3. The examples were fired in a works kiln of the intermittent variety. The firing (i) took 12 days to complete and the maximum temperature reached was 1,430°C. (Cone 15). Certain samples of each type were then submitted to a second firing (ii), which was completed in 15 days, a temperature of 1,490°C. (Cone 18) being attained. Of the resulting products, those with Fe_2O_3 were particularly compact and resistant to compression at ordinary temperatures. The density of all the samples was determined, and microscopical examinations were made in order to discover the nature and degree of the quartz transformation which had taken place.

Density.—The density was determined on the powdered samples with the pycnometer, benzol being used as the immersion liquid. The following values were obtained:

Samples submitted to one fire (i.)		Samples submitted to two burns (ii.)	
Normal mixture	2·50	Normal mixture	2·31
,, ,, with 1·5 Fe_2O_3	2·48	,, ,, with 1·5 Fe_2O_3	2·32
,, ,, ,, 1·5 P_2O_5	2·51	,, ,, ,, 1·5 P_2O_5	2·31
,, ,, ,, 1·5 CaO	2·51	,, ,, ,, 1·5 CaO	2·32
,, ,, ,, 0·5 B_2O_3	2·43	,, ,, ,, 1·5 B_2O_3	2·32
,, ,, ,, 1·0 B_2O_3	2·40		
,, ,, ,, 1·5 B_2O_3	2·42		

The first series of results shows that boric oxide accelerates greatly the transformation of quartz, its action in this respect being far superior to Fe_2O_3 or P_2O_5. The second series of values illustrates the powerful effect of temperature and duration of firing on the transformation of quartz into its forms of lower specific gravity. Even in the normal product, the transformation is almost complete.

Microscopical examination.—Thin sections of the one-fire (i.) samples showed that only a small portion of the quartzite had been transformed. It was also noted that the minute crystals of tridymite tended to collect at points where grains of ferric oxide were visible. The samples containing P_2O_5, WO_3, and CaO did not exhibit any substantial variations from the normal, with the exception of a larger proportion of calcium silicate in the last mentioned. In the samples containing Fe_2O_3, however, minute crystals of tridymite occurred much more frequently in the mass of cristobalite uniting the unaltered quartzite grains than was the case in the normal body. Of particular interest were the samples containing an addition of B_2O_3. Adjacent to the unaltered quartzite, large crystals of tridymite immersed in the mass of crystobalite were observed. These crystals frequently assumed the characteristic spear-headed twin form. Thin sections of the samples which had been subjected to two burns (i. and ii.) exhibited slight birefringence; the quartzite had been completely transformed. The larger particles had changed to cristobalite and were embedded in a matrix consisting of cristobalite and numerous crystals of tridymite of varying dimensions. The

samples containing Fe_2O_3, and B_2O_3, presented more advanced tridymite formations, which were particularly well developed in those to which B_2O_3 had been added. It is concluded that it might be worth while to make use of B_2O_3 as a catalyst in practice, since its action in aiding the transformation of quartz is so powerful, even if it is present to the extent of only 0·5 per cent. Iron oxide also has an appreciable catalytic action, due to the formation of ferri-silicates, which, like the alumino-silicates formed from the alumina present, give mixtures which fuse at comparatively low temperatures. This phenomenon is not so readily detected by density determinations as by microscopical examination.

SINTERING; ITS NATURE AND CAUSE.—R. C. Smith (*J. Chem. Soc.* **123,** 2,088, 1923). It is shown that: (1) Sintering may take place in crystalline and in amorphous substances. (2) The sintering of a crystalline substance is due to a change in the size of the crystals or to the formation of an allotrope. (3) The sintering of an amorphous substance is due to the formation and growth of crystals.

THE SINTERING PROCESS IN CLAYS.—(*Südd. Tonind.*, **5,** 514, 1923). The subject is treated in a simple, general manner.

COLLOIDAL CLAY.—D. Casimiro Burgués y Escuder (*Mem. acad. cienc. artes.*, **17,** No. 19, 1922). Mainly a resumé of previous work. Air-dried clay in portions of 10 grs., ground to pass 1 mm. mesh, was shaken with 200 cc. of 1 : 1,000 solutions of different dyes, and the quantity of unabsorbed dye in each solution was determined colorimetrically. The following volumes of 1 : 1,000 dye solution, if diluted to 50 cc., match the colour of the unabsorbed dye solution: "Crystal violet O" 4 cc.; "conc. acid green" 10 cc.; "dianiline red" 10 cc. "Methylene blue" was almost completely absorbed, and fuchsin in large crystals even more so. The presence of $CaCO_3$ in the clay did not alter its power to absorb methylene blue. It is indicated that the amount of dye absorbed is not a satisfactory measure of the colloidal matter in a clay, because other components may also absorb dye.

II.—MANUFACTURING PROCESSES:

GENERAL.

MODERN METHODS OF MAKING GLASS HOUSE REFRACTORIES.—(*Cer. Industry*, **1,** 170, 1923). A well illustrated description is given of the methods employed at the plant of the Buckeye Clay Pot. Co., of Toledo, Ohio, which concern has supplied the glass manufacturers with every type of glass works refractories for many years.

Mixing and Making Methods.—Much study has been devoted by the Company to the handling of raw materials. The floor of the mixing-house is on a level with the floor of the waggons on the railway siding which runs alongside. All materials are weighed accurately on a calibrated scale, and are then dumped into the hopper of a preliminary crusher, of which there are three, one for each type of refractory. The grog and clay are crushed together and pass directly to a bucket elevator which conveys the crushed material to storage bins of approximately 45 tons capacity. A disc feeder attached to the bottom of the bins permits a uniform feed of material to a belt conveyor, which delivers the clay to the dry pans. From these it is fed to vibratory sieves and is again elevated to smaller storage bins, where the disc feeder is again employed to secure a uniform flow of dry ground batch to a double-shafted open-top pug-mill. The pugged clay column is conveyed directly to a storage bin, where it is aged a short tine and then pugged again. It is pugged a third time before being moulded into tank blocks or other refractories. The mixture has to be adjusted to the use to which the product is to be applied. For instance, the blocks used in the floor of a large glass tank contain coarser grog than those used in laying up the sides. Another set of grinding machinery is employed to prepare the clay for making glass

pots. Chaser mills, vibratory sieves, elevators, and steel bins with disc feeders are made use of in this case also. The mixture is aged somewhat longer than that for blocks, longer ageing giving increased plasticity and burned strength. The pots, both open and covered, are carefully built up by hand. After drying for about a month, the pots are tilted over for the purpose of allowing the bottom to dry. After six months they are dispatched as ready for use.

Tank Block Machine.—As the result of much experimenting, a special stiff mud machine was finally installed at the works. This machine will produce 40 blocks per hour and operates on a principle similar to a brick machine. As the column of clay issues from the die, it slides on to a reciprocating table. Water is used to lubricate the die, which is fitted with steel liners. The latter project in the form of slightly bent aprons and serve to guide the clay block. Columns of a sufficient length are cut off with a wire. A novel piece of apparatus is then brought into play. This consists of a suction plate, which fits the top of the clay block. Suction is induced when the plate has been adjusted, and the block is lifted by means of an electric hoist and placed upon a pallet covered with wire netting and coarse grog to facilitate drying. The pallets are so formed that they can be tiered three high, and an electric truck conveys the tiers to the drying-rooms, or humidity dryers.

Drying.—The temperature in the dryers is maintained by means of steam coils on opposite sides near the bottom; these produce convection currents of hot air saturated with moisture from the blocks. The drying ovens are constructed with walls of porous bricks, which act as "blotters," and allow a uniform diffusion of moisture and a corresponding evaporation from the outer surface. The roof is covered with gypsum tiles. Humidity control is available for emergency, but is seldom used owing to the efficiency of the porous brick wall. With the heating schedule used, drying takes place comparatively quickly, without danger of damaging the ware. About seventy blocks, measuring $12 \times 18 \times 24$, can be stored in one of these ovens, and the drying time has been reduced from 6-10 weeks (according to the size of the block) to about twenty days. After being in the ovens for about two weeks, the blocks often feel distinctly wet to the touch, showing that drying is taking place from the centre outwards.

Rubbing Machine.—When thoroughly dry, the blocks are conveyed by mechanical means to the rubbing tables. A new machine, which will square all four sides of the green blocks in one setting, is being built and will, when in operation, eliminate much labour. The machine consists of a double rail placed in the form of a square, the rails being set far enough apart to support a car, consisting of a level steel plate mounted on rollers. At each one of the four corners there is an ingenious switch arrangement, which turns the block so that the opposite sides face the carborundum rubbing wheels. By means of suction fans and large pipes the dust is collected in steel reservoirs.

Firing.—Fuel oil is used in firing the kilns, which are of the rectangular down-draught type. The schedule is as follows: 5 days to 600°F.; 3 days from 600 to 1,500°, and a further two hours to the maturing temperature of 2,500°F., after which the kiln is closed tight and allowed to cool very slowly. About $10\frac{1}{2}$ days are required to burn off a kiln.

Cutting Machine.—To facilitate the filling of emergency orders for sizes of blocks, etc., not in stock, a carborundum toothed saw, 5 ft. in diameter, has been installed. It is claimed that this saw will cut burned refractories to the size required in a fraction of the time necessary to cut them by hand, and the ware is left with a perfectly smooth surface.

THE MANUFACTURE OF GLAZED BEADS OF CLAY.—(*Ker. Rund.*, **31**, 145, 1923). Beads are usually made of porcelain or earthenware. They can, however, be manufactured from clay, provided that a light-burning variety is used, quartz and felspar being added if necessary. They are best made in presses, using moulds which turn out five or six beads at a time.

The body used in this process must be dried and powdered, moistened with oil and water, and thoroughly mixed. The pressed beads should be dried prior to the removal of the seam, biscuit fired to about cone 010a and coated with a glaze which matures at 1,000° to 1,050°C. They can be smoothed and cleaned mechanically in small, rotating wooden drums into which a little fine sand has been introduced. The glazing operation must be done with great care and cleanliness to ensure a good quality of bead. It is simplified somewhat if the beads have holes. To prevent the glaze covering over the holes, the beads should be threaded loosely on a wire greased with tallow The film of glaze should be as thin as possible. In the glost oven the beads should be placed on well-formed pin points; the finer the points the less conspicuous are the unglazed stilt-marks. The best flow-glaze is one containing red lead to which colouring oxide can be added. Tin glazes are most suitable for coating purposes.

COMPOUNDING AND PREPARATION OF BODIES, ETC.

SAND AS SHORTENING MATERIAL.—(*Südd. Tonind.*, **5**, 264, 1923). Sand should be used with caution as a shortening medium for making bricks, tiles, etc. The irreversible expansion of quartz in the fire tends to produce cracked or crazed ware. An instance is given in which two varieties of sand had to be abandoned in favour of ground grog.

BONELESS CHINA.—F. A. Rhead (*Pot. Glass Rec.*, **5**, 499, 1923). The compositions of the continental hard and soft porcelains are compared with that of English china bodies, and, in view of the high price of bone, it is suggested that the production of boneless china body at present firing temperatures ought to be possible. Ground glass was formerly used in English bodies before Frye took out his patent in 1749 for improving china with the addition of bone ash.

WEATHERING.—(*Südd. Tonind.*, **5**, 516, 1923). Recourse is now rarely made to the process of weathering in the preparation of clays on brickworks. The author suggests that it might be revived with advantage in certain cases.

TESTS ON SOME SAGGAR CLAYS AND BODIES.—R. Twells (*J. Amer. Cer. Soc.*, **6**, 949, 1923). An investigation was carried out during the autumn of 1920, in the Research Laboratory (Porcelain Department) of the General Electric Company, at Schenectady, the main object of which was to develop a relatively cheap saggar body, which would have a longer life than those now in use. Three typical saggar clays were used in the experiments, viz.: No. 8 Buff Clay—a plastic fire clay, No. 1 Fine Clay—a plastic fire clay, and No. 1 White Sandy Clay—a short, sandy clay. Tests were first conducted on these clays without the addition of grog, the composition of the four test-pieces being as follows:—

Designation of Test-piece.	B.	F.	BS.	BF.
No. 8 Buff Clay	100%	—	62%	62%
No. 1 Fine Clay	—	100%	—	38%
No. 1 White Sandy Clay	—	—	38%	—

The clays were ground to pass a 20-mesh, mixed carefully dry, then moistened, and wedged thoroughly. Test bars measuring $1 \times 1\frac{1}{2} \times 4\frac{1}{2}$ inches were dried in a Procter humidity dryer in 30 hours, and 5 test-pieces from each body were fired in a tunnel oven to cone $10\frac{1}{2}$. These bars were then tested for linear shrinkage, transverse strength (dry and fired), absorption of moisture, and dye penetration. The results of these preliminary tests indicated that the substitution of the plastic No. 1 Fine Clay for the short No. 1 Sandy Clay in a mixture containing no grog gave a weaker body in the dry state, but a much stronger body in the fired state. Similar experiments were then undertaken on saggar bodies, with varying additions of grog. After being fired to cone $10\frac{1}{2}$, these bars were tested for resistance to heat changes,

in addition to the above-mentioned tests. Three grades of grog were used, having the following screen analyses :—

	Grog No. 1	Grog No. 2	Grog No. 3
4–6 mesh ..	55·6%	—	—
6–10 ,, ..	36·4%	82·0%	—
10–20 ,, ..	6·2%	14·0%	—
Finer than 20 mesh ..	1·8%	4·0%	100%

The results of this series of tests bring out the following points : (1) The substitution of the plastic No. 1 Fine Clay for the No. 1 White Sandy Clay increases the shrinkage, decreases the dry, and increases the fired transverse strength ; (2) the substitution of the medium grog (N. 2) for the coarse (No. 1) increases both the dry and the fired strength, and the resistance to heat changes ; (3) the replacement of 10% of clay by 10% of fine grog doubles the dry strength, increases the fired strength, and increases the resistance to heat changes ; (4) the replacement of 5% of fine grog (No. 3) with 5% of talc increases (*a*) the shrinkage, (*b*) the dry and fired transverse strength by approximately 50%, and (*c*) the resistance to heat changes. Similar results were obtained by substituting asbestos in place of talc ; (5) an increase of 6% in the total percentage of clay at the expense of coarse grog (No. 1) combined with an increase of 8·8% of No. 1 Fine Clay has the effect of increasing the fired strength by about 50%, but reduces the resistance to changes of temperature by over 33⅓%. The best body of this type had the composition : 29·8% of No. 8 buff clay ; 18·2% No. 1 fine clay ; 42% grog No. 2, and 10% grog No. 3. This body was submitted to a works test, 100 saggars being prepared in the ordinary way. Records were kept only as far as the fifth fire, after which it was found that three saggars were broken, fifteen were slightly cracked, while 63 were flawless. This result seemed to justify the conclusion that the primary object of the investigation had been attained. A body was produced which was better than the regular mixture in use, and which was obtained from relatively cheap materials. A third series of tests was carried out, which differed from the others in that less common materials were employed. Two bodies included in this series proved to be much superior to any other previously tested. They contained : (1) 35% Georgia kaolin, 10% Tennessee ball clay, 55% ordinary saggar grog (10-40 mesh), and (2) 40% Kentucky ball clay, 60% medium sized carborundum firesand. Though the initial cost of saggars made from these materials would usually be considered too high, it is at least probable that, as regards their relative "cost per fire", they would be comparable with the cheaper varieties.

SHAPING, MOULDING, DRYING, ETC.

CASTING SANITARY WARE ; CHICAGO POTTERY CO.—(*Cer. Ind.*, **1**, 131, 1923). After spending much time and money in investigating clays, this firm finally decided that American clays were not best suited to the manufacture of their product. They now use English china clay, together with English ball clay, flint and felspar for the production of their ware. These materials are stored in large bins. After being carefully weighed, the material is dumped into the blungers, of which there are two, with a capacity of five tons each. It is blunged for a period of one, to one and a quarter hours, and then run through the magnetic separator and through 120-mesh sieves. From the magnetic separator, the slip runs into a storage agitator of 15 tons capacity. The blunger ball mill and agitator are lined with imported flint blocks. From the agitator, the slip is pumped up through the filter press, from which the material, in the form of plastic cakes about two feet square and 1½ inches thick, is passed into another blunger and mixed with a known amount of water to produce a definite consistency. When this mixture has

been blunged sufficiently, specified quantities of sodium silicate and sodium carbonate are added, in order to give the slip the fluidity necessary for casting purposes. To ensure a constant supply of casting slip, two huge tanks, with a capacity of 50,000 gallons of clay slip, which is agitated continually, are placed in an elevated position in the casting shops. In casting the ware, the various moulds of the different parts are placed on opposite tables, the bowls on one side and the trap moulds on the other. The tables are about two feet high. Above the tables, pipe lines conduct the slip by gravity from the slip tanks. About 20 washdown moulds can be placed on a table. The moulds are made in two or three pieces, according to the type of product to be cast. Approximately 40 moulds can be filled in the time it would take to make one piece by the hand-pressing method, and twice as many pieces can be finished in a given time. Moving down the aisle between the tables, the potter first fills a washdown mould, and then, turning to the opposite table, fills the trap moulds, so that, when he is ready to attach the clay trap to the washdown, both pieces will contain approximately the same amount of moisture—a point of obvious importance. After about an hour, the casting process is finished, but before the piece of ware is removed from the mould, the latter is opened slightly to allow the clay article to shrink from the mould so that it can be removed without injury. The mould is left to dry overnight and used next day; about 200 pieces can be cast before a mould is unfit for further use. Seven periodic updraught kilns are used for firing the ware, and six different types of saggars are employed, to ensure the most economical use of kiln space. A gang of five men can set a kiln with bungs 20 saggars high in a day. Each kiln has a capacity of over 500 pieces of ware. Special fireclay blocks, measuring 6 by 6 by 10 inches, are made at the plant to ensure a thoroughly tight kiln wicket. Cones and pyrometers are used to guide the firemen. After a short water-smoking period, the kiln is fired up to cone 9, and held at that temperature for a few hours, after which the kiln is allowed to cool slowly. In two days the temperature has fallen to 125°F., when the kiln is opened. The biscuit ware is dipped in a lead-borate glaze of medium hardness. To save time in setting, the dipped pieces are moved to an opening in the wall which leads directly into the kiln. The glost oven is run slowly up to 1,050°F. and then carried more quickly up to 2,296°F. The soaking period is not so lengthy as in the biscuit burn, but the cooling rate is the same.

PRESSING TERRA COTTA.—J. Clark (*J. Amer. Cer. Soc.*, **5**, 623, 1922). Some practical suggestions on correct methods of pressing are illustrated by seven photographic plates.

GOOD AND BAD PRACTICE IN THE PRESSING DEPARTMENT.—T. A. Klinefelter and F. C. Parsons (*J. Amer. Cer. Soc.*, **5**, 632, 1922). Correct and incorrect methods of pressing terra cotta are illustrated.

THE HEAT CONSUMPTION OF AN ARTIFICIAL BRICK DRYER.—H. Manuel (*Tonind. Ztg.*, **47**, 597, 1923). The method of arriving at the amount of heat required to dry a given daily output of bricks is explained.

DRYING.—W. E. Lemley (*Brick*, **64**, 26, 1924). A discussion of the general principals of drying is accompanied by an account of the methods and apparatus employed at the Denny Renton Clay and Coal Company's plant at Seattle.

Patents.

MOULDING CUP HANDLES, ETC.—E. Hawley (*Pat. J.*, 1,811, 1923). No. 201952, 1 Nov., 1922. Relates to the casting and moulding of hollow-ware; presses with fixed moulds; pressing plungers and dies.

DRYING, GRINDING AND MIXING APPARATUS.—T. W. S. Hutchins (*Pat. J.*, 1,811, 1923). No. 201,966, Apr. 3, 1922. Rotary cylinder apparatus for drying or calcining pulverised material, slaking lime, etc., is provided with tumblers, which agitate and pound the material and keep the inner surface of the cylinder clear of adhering matter.

ELECTRIC INSULATORS.—A. Renandin (*Pat. J.*, 1,815, 1923). No. 203,552, Oct. 6, 1922. Addition to *Spec.* 186,632. A protector as described in the parent specification for connecting-ligatures, consists of two substantially semi-cylindrical members connected rigidly together by bolts, and provided on their rims with a series of recesses, adapted to engage with corresponding projections on the adjacent insulators.

FIXING LAVATORY BASINS, ETC.—Twyfords, Ltd., and J. T. Webster (*Pat. J.*, 1,817, 1923). No. 204,225, Oct. 23, 1922. Basins, sinks, etc., are formed, according to the invention, with an undercut recess for engagement with the head of a bolt, by means of which they are secured, with the aid of a spring and nut, to a seat formed on the support.

FIXING LAVATORY BASINS.—R. G. Howson (*Pat. J.*, 1,818, 1923). No. 204,402, June 29, 1922. The top of the pedestal is so shaped as to enable an ordinary basin to be secured in position by means of a clamping bar.

TEAPOT LIDS.—W. G. Barratt (*Pat. J.*, 1,818, 1923). No. 204,597, Dec. 5, 1922. A method of attaching an infuser to a teapot lid is described.

VENTILATION BRICKS.—G. H. Carter (*Pat. J.*, 1,820, 1923). No. 265,221, July 18, 1922. A special shape of brick for use in ventilating buildings is described.

ROOFING TILES.—R. Y. Ames and G. G. Scott (*Pat. J.*, 1,825, 1924). No. 206,742, Jan. 6, 1923. Roman, or Italian tiles are so shaped that the horizontal joints have only three thicknesses of tiles at the battens.

ELECTRIC INSULATORS.—Soc. Ceramica R. Ginori (*Pat. J.*, 1,826, 1924). No. 207,147, Apr. 16, 1923. A pivotal connecting system for suspension insulators is described. The pivot is made deformable.

TEAPOTS; SHAPES.—R. H. Taylor (*Pat. J.*, 1,828, 1924). No. 208,074, Apr. 11, 1923. The spout section is formed "stream lined," *i.e.*, merging into the body without any shoulder or definite line of junction. The body and spout portions are separated by a perforated partition. The spout lip is shaped to prevent dripping.

JUGS, TEAPOTS, ETC.; SHAPES.—W. G. Barratt (*Pat. J.*, 1,829, 1924). No. 208,364, Dec. 5, 1922. Teapots, etc., are formed with non-projecting handles shaped to correspond in outline with the opposite side of the vessel. The edge of the mouth is curved outwardly to form a pouring lip. The vessel may have a perforated shelf for retaining tea leaves, or it may be fitted with an infuser.

KILNS, OVENS, MUFFLES; FIRING TECHNIQUE, ETC.

GAS-FIRED ENAMEL KILNS.—Rehmann (*Ker. Rund.*, **31**, 359, 1923). A gas-fired enamel kiln, which has recently been put on the market by the firm Zahn & Co., of Berlin, has a large chamber, measuring 23 by 16 by 16 ft., within all parts of which it is possible to ensure a uniform heat. The oven is gas-heated from three combustion chambers built in the solid foundations, gas and air being supplied under pressure from these chambers. The gas ignites in the fore part of the muffle, *i.e.*, where the greatest loss of heat occurs through opening the doors. The fire can be made to pass through flues directly into, and across the muffle if required, or the hot gases can be passed round the outside only. By means of a series of baffles in the outer flues, the heat can be conducted to any part of the muffle walls as required. The result is an exceptionally uniform distribution of heat. The hot gases are remarkably free from dust or ashes, provision being made for collecting such ingredients in a water bath below the generators. In consequence, the furnace refractories are subjected to little abrasion. The elimination of flying dust is further facilitated by blowing the necessary air into the generator above the grate. The kiln foundations are built of ordinary bricks and not of thin refractory walls. They enclose gas and air preheaters constructed on a massive scale,

the effect of which is intended to counterbalance the great loss of heat when large objects have to be run into, or out of, the kiln.

A NEW DECORATING KILN.—C. E. Doll (*Cer. Ind.*, **1**, 180, 1923). For the firing of decorated ware, a new type of kiln was placed in operation at the Mt. Clemens Pottery Co., Mt. Clemens, Mich., in April, 1922. This kiln has a capacity of over 3,000 dozen of semi-porcelain dinner ware for a 24-hour day, and it can be operated either continuously or intermittently as desired. It is built of fire brick and insulating brick within a steel shell. The weight of the cars is carried by floor beams through the brickstays to the floor. The height of the rail is 16 inches above the floor, thus giving convenience of loading and unloading. As at present operated, the kiln is 125 ft. in length, and has a double combustion chamber near the centre, with gas flues leading toward the charging end and thence through an overhead flue to the stack. The ware is protected from the direct action of flue gases by a carborundum muffle. Cooling air is forced in at the exit end, and is gradually heated until it passes the combustion chambers. It then continues to the charging end, where it is withdrawn. It circulates through the ware, heating it by convection. The ware is stacked in bungs on interlocking, cast-iron cars which are pushed into the kiln at a uniform rate of from 4 to 5 inches per minute. Each car has three shelves, measuring 20 in. by 40 in. Cast-iron sand seals in the kiln and on the cars prevent escape of heat. The bottoms of the cars are filled with insulating cement. A transfer car at each end of the kiln delivers to the charging end and receives at the exit end. These cars move to a return track running parallel to the kiln. The finished ware is removed from the cars while on the return track, and the empty cars are moved on periodically by air cylinder toward the charging end. All the pushers are operated by air cylinders from a central control table with the exception of the kiln charging pusher, which is an oil gear pusher. Steel vestibules at the ends of the kiln prevent the escape of air while cars are entering or leaving. An accurate and constant check of the temperature is possible by the use of pyrometer couples, fixed along the hot zone and leading to a recording instrument. Two of these couples are fixed equidistant from the centre line of the kiln, thus enabling the operator to determine at once the temperature of either burner. Oil at from 40 to 50 lbs. pressure is used as fuel, and low-pressure air for the burners is preheated by passing through a duct immediately above the fire-brick kiln arch at the cooling end. This gives a constant supply of air at 150 to 200° for combustion purposes. The advantages of this tunnel kiln over the old periodic or other types of continuous decorating kilns are summarised as follows : (1) economy in, and independence of labour, since unskilled assistance can be applied successfully to the operations; (2) the economy in fuel is said to amount to 80 per cent. ; (3) increase in the quantity of production in a given time ; (4) the quality of the work both in gold and colour cannot possibly be attained in other types of kilns ; (5) reduction of the losses from ware spoiled or damaged in firing.

FIRST MARLOW KILN IN AMERICA.—(*Cer. Ind.*, **1**, 240, 1923). The first Marlow tunnel kiln in America was put into operation in September last at the plant of the Mosaic Tile Co. The kiln is of the open-fired recuperative type and is 332 ft. long. The width of the setting space on the trucks is 52 inches, and the vertical setting space is exactly 6 feet. The trucks carry 108 saggars each and the kiln holds 54 trucks at a time. The cars are not sand-sealed, but are built with staggered side construction. They are pulled, and not pushed, through the kiln by means of a 3 h.p. motor. A simple coupling device automatically connects one truck to the next. It is claimed that drawing the trucks keeps a better line than pushing, and, moreover, requires less power. The air used for combustion is first preheated by being drawn through flues along the tunnel and is still further heated as it passes through the firing zone. This air meets the incoming combustion gases, which have also been preheated. The volume of air admitted is regulated by the expansion of the gas and the size of the orifice through which it enters the combus-

tion chamber. This in turn is regulated by the temperature of the hot zone, and thus a semi-automatic operation is obtained. A 30-inch fan, driven by a 10-h.p. motor, regulates the flow of gases. The kiln is fired with natural gas, there being four burners on each side. For vitreous ware, fired to cone 10-11, the estimated schedule for the trucks will be $1\frac{1}{2}$ hours, while for glost burns to cone 2 the car interval will be 45 minutes. It is claimed for this kiln that absolute uniformity of temperature throughout the entire cross section in the hot zone can be attained ; and further, that it is possible to vary the temperature up to 70°F. between the bottom and the top of the trucks, *i.e.*, the temperature at the bottom can be maintained 70° higher than at the top, and *vice versa*.

BURNING CHINA WARE IN GAS-FIRED KILNS.—(*Brick Pot. Tr. J.*, **31**, 134, 1923). The method of firing, adjustment of air and gas pressure, etc., are explained. After the first hour, the following readings should be obtained, or the necessary adjustments made to produce them : (*a*) gas pressure at each burner should be $\frac{1}{12}$ in. water column ; (*b*) kiln draught 20 in. above the floor should be $\frac{1}{50}$ in. ; (*c*) gas outlet to each burner should be 20 sq. in ; (*d*) air inlet at each burner 70 sq. in. ; (*e*) kiln gases should contain 14·5% CO_2, about 5% oxygen, and no CO. During the first stage of 10 hours the temp. rises to 930-950°C. Under proper conditions, gas-firing proves cheaper in fuel and labour than coal-firing, and the wear and tear on saggars is much less.

A STUDY OF LIME KILNS.—A. E. Truesdell (*Rock Prod.*, **26**, No. 8, 23, 1923). An introduction to a series of articles, dealing with the discovery of lime, process of manufacture, kilns, etc.

RECENT DEVELOPMENTS IN POTTERY FIRING.—(*Pot. Gaz.*, **49**, 108, 1924). An account is given of the Marlow Kiln, recently installed at Zanesville, and of the Shaw kiln, 5 illustrations.

Patents.

FURNACE LININGS.—E. Bong (*Pat. J.*, 1,814, 1923). No. 203,062, June 6, 1922. A refractory lining for furnaces, converters, gas-producers, etc., consists of quartz rock in lumps (5 to 15 mm.) and a binding-agent such as triturated fire-clay. The mass is stamped in position in the usual way, and to prevent interfusion between the lining and the brickwork a layer of graphite is preferably interposed.

REGULATING AIR SUPPLY TO GAS PRODUCERS.—M. Birkner (*Pat. J.*, 1,814, 1923). No. 203,270, May 25, 1922. A method is described by which the speed of the discharge rollers at the base of the producer may be regulated by the variation in the temperature in the upper zone of the producer.

ROTARY CEMENT KILNS.—N. Windqvist (*Pat. J.*, 1,815, 1923). No. 203,673, Aug. 23, 1923. Addition to *Spec.*, 126,230.

TUNNEL KILNS.—W. H. Fitch (*Pat. J.*, 1,811, 1923). No. 202,194, Sept. 26, 1922. The air for combustion is heated in pipes extending through the cooling-zone and the waste gas flue. The kiln illustrated comprises a pair of tunnels arranged side by side, the heating sections being set in a pit, or emplacement. Beneath the heating section of each tunnel is a series of combustion chambers, which are fired by burners, and which communicate with the tunnel at their inner ends through flared up-casts. On the opposite side of the tunnel are dampered down-casts leading to a waste gas-flue. An arrangement for pre-heating air for combustion is described.

MECHANICAL STOKERS.—J. Procter (*Pat. J.*, 1,811, 1923). No. 202,204. Oct. 23, 1922. Additional to *Spec.*, 181,090, describing apparatus for supplying fuel to top-fired continuous kilns.

SPECIAL SHAPES OF FURNACE BRICKS.—American Arch Co. (*Pat. J.*,

1,813, 1923). No. 202,788, June 20, 1922. A method of constructing furnace arches with special bricks is described.

MUFFLE FURNACES. F. J. Tone (*Pat. J.*, 1,807, 1923). No. 200,506, July 3, 1923. According to the specification, the roof and the upper parts of the side walls of the muffle are built of silicon carbide tiles, and the surrounding walls of firebrick and insulating bricks.

FURNACE CASTINGS AND WALLS.—M. Liptak (*Pat. J.*, 1,809, 1923). No. 201,442. A method of wall construction is described, by which a permanent outer wall and a replacable wall, including shelf-forming blocks, are produced. Courses of firebricks are supported by the shelf blocks.

CHAMBER KILNS.—C. Dean, J. W. Redfern and A. E. Osman (*Pat. J.*, 1,811, 1923). No. 202,061, May 17, 1922. Modifications, mainly in the flue arrangements of down-draught continuous kilns, are described. The chambers are arranged in two lines with end cross connections. At one end of each chamber is an upcast flue leading from the floor flues of the preceding chamber. Beneath the floor of each chamber are transverse flues leading to the upper parts of side longitudinal flues which discharge into a transverse flue at the furnace end of the succeeding chamber.

GLAZES, ENAMELS.

ACID-RESISTING ENAMELS.—(*Chem. Tr. J.*, **72**, 351, 1923). The article deals with the preparation, properties and industrial uses. The chief constituents are silica, alumina, lime and magnesia. The quartz used must be as pure as possible. A small addition of tin oxide improves the whiteness and opacity, but impairs the acid-resistance. The enamels have hitherto been found applicable to cast iron only. The principal steps in the manufacture, such as the preparation of a good ground mass, the application of covering layers, etc., are briefly described. The acids most injurious to these enamels are: hydrofluoric, acetic, and formic. The advantages of acid-resisting enamels in the construction of chemical plant are discussed in some detail.

ENAMELLED SIGN-MAKING BY THE FEDERAL ELECTRIC CO., OF CHICAGO.—(*Cer. Ind.*, **1**, 178, 1923). An illustrated account is given of the modern machinery, etc., installed at the above plant. By a re-arrangement of the routine schedule, operating expenses have been reduced, and it is claimed that the works are now able to produce 560 sq. ft. of enamel signs every working hour.

ZIRCONIUM FOR WHITE GLAZES.—P. P. Budnikov (*Tonind. Ztg.*, **47**, 173, 1923). The author undertook experiments with a view to replacing tin by other substances. Antimony oxide imparts to the glaze an opaque, white colour of a fairly pure tone and good gloss. White arsenic (As_2O_3) converts transparent glazes into white opaque glazes, but it is somewhat unstable and decomposes at high temperatures. A glaze made with bone ash readily tends in the oven to collect soot, etc., which can only be removed with difficulty. The best results were obtained with cryolite, which may be replaced by a mixture of china clay or felspar with fluorspar. In order to make the glaze coincide with the body as regards coating power and expansion, red lead, zinc oxide, lime, etc., may be added to the former. The results, however, are more reliable if zirconium compounds are added to the glaze. Even 5 per cent. of zirconium dioxide will give a very white opaque glaze. Still better results are possible with a mixture of tin oxide and a zirconium preparation. If the zirconium is added to the mill mixing the melting point of the glaze is raised. The tests also showed that the addition of tin or zinconium in the form of the hydrate or basic compound improves the covering power of the glaze. The materials added as opacifiers to the glaze are probably present in the form of a highly disperse solution. The following two results of the tests are given :—

Sample 1.		Sample 2.	
5 parts by wt.,	ZrO_2	7 parts by wt.,	SnO_2
34 ,, ,, ,,	Pb_3O_4	3 ,, ,, ,,	ZrO_2
10 ,, ,, ,,	china clay	32 ,, ,, ,,	Pb_3O_4
14 ,, ,, ,,	Na_2CO_3 (calcined)	35 ,, ,, ,,	SiO_2
1 ,, ,, ,,	$CaCO_3$	10 ,, ,, ,,	china clay
1 ,, ,, ,,	ZnO	12 ,, ,, ,,	Na_2CO_3 (calcined)
35 ,, ,, ,,	SiO_2	1 ,, ,, ,,	ZnO

The molten frit is poured into water and then finely ground.

THE EFFECT OF THE FRIT-CONTENT OF A GLAZE ON CRAZING.—(*Sprech.* **56**, 243, 1923). The properties of the different glazes used in the pottery industry frequently vary to a considerable degree; there are elastic and brittle glazes; glazes which are extremely sensitive to the action of kiln gases, and others which are scarcely affected thereby. A danger which is constantly threatening the earthenware industry in particular is the crazing of the glaze. This trouble, which frequently does not become apparent until after the lapse of some months, is due to differences in the coefficient of expansion of body and glaze. On the other hand, a sufficiently elastic glaze will adhere to a body without crazing, even though the coefficients of expansion show considerable variation. A serious defect which favours the tendency to the production of crazed ware, is the uneven temperature in the biscuit and glost ovens. In the former, this lack of uniformity can be overcome to some extent, even if serious faults in the construction of the kiln have to be contended with; but in the glost oven, in which definite kiln atmospheres have to be maintained, this is only possible by reconstructing the kiln. These variations in temperature often exceed 100°C. In order to render a glaze as insensitive as possible to great variations in temperature, it is very important to fix the frit-content as high as possible, and thus lower the melting-point of the glaze. The frit-content is often reduced to a ridiculous minimum with the object of economising, but the opposite result is actually obtained, since faults occur which would not appear with more frit present.

DISCOLORATION OF COBALT ENAMEL.—(*Ker. Rund.*, **31**, 145, 1923). A porcelain plate, having a cobalt blue enamel body, was used for domestic purposes to cover beans in a salt solution. On removing the plate from the brine after 4 or 5 months, it was noted that the blue border had changed to a bright lilac colour, whilst a gold line running parallel with the blue, had not been affected. Cobalt oxide does not combine completely with the porcelain ingredients; a small portion remains in the porcelain in a free condition. This portion combined with acids, formed in the salt solution, to produce red salts of cobalt (only the anhydrous salts of cobalt are blue). This would explain the bright lilac colour. The blue colour would be restored if the plate were fired again, since a comparatively low heat would suffice to remove the acids absorbed by the porcelain.

FURTHER STUDIES OF PORCELAIN GLAZES MATURING AT HIGH TEMPERATURES.—R. Twells (*J. Amer. Cer. Soc.*, **5**, 1113, 1923). The investigation covers three fields of glazes: Series A contains 21 glazes with variations in composition as shown in the formula:

$$\left.\begin{array}{r} 0{\cdot}3\ K_2O \\ 0{\cdot}2 \text{ to } 0{\cdot}7\ CaO \\ 0{\cdot}0 \text{ to } 0{\cdot}5\ BaO \\ 0{\cdot}0 \text{ to } 0{\cdot}5\ MgO \end{array}\right\} 1{\cdot}3\ Al_2O_3(11{\cdot}0\ SiO_2)$$

Series B contains 10 glazes, each having the formula:

$$\left.\begin{array}{r} 0{\cdot}3\ K_2O \\ 0{\cdot}7\ CaO \end{array}\right\} 1{\cdot}3\ Al_2O_3\ (11{\cdot}0\ SiO_2),$$

but having their clay-content varying triaxially between Florida kaolin, North Carolina kaolin, and Kentucky ball clay. Series C contains 20 glazes with variations in composition as shown in the formula:

$$\left.\begin{array}{r} 0{\cdot}2\ K_2O \\ 0{\cdot}8\ CaO \end{array}\right\} 0{\cdot}8 \text{ to } 1{\cdot}6\ Al_2O_3\ (8{\cdot}0 \text{ to } 14{\cdot}0\ SiO_2).$$

The corner

glazes of each series were ground wet for 18 hours, and cross blended to produce the intermediate glazes. The glazes were applied by dipping the green porcelain discs and fired in periodic and tunnel kilns to temperatures between cone 16½ and cone 19 down. They were then examined with the naked eye with a 10-x pocket lens. The body used contained 5 per cent. English ball clay (M and M), 12 per cent N. Carolina kaolin, 8 per cent. Florida kaolin, 30 per cent. English china clay (M.W.M. No. 2), 30 per cent. flint and 15 per cent. felspar. In series A the effect of replacing CaO by MgO and BaO in one of the best glazes from the previous work was studied. The glaze chosen as a basis was: $\left.\begin{matrix}0{\cdot}3\ K_2O\\0{\cdot}7\ CaO\end{matrix}\right\}$ $1{\cdot}3\ Al_2O_3 : 11{\cdot}0\ SiO_2$. It was found that, within the limits of the experiments, the triaxial replacement of CaO by MgO and BaO did not produce a noticeable change in the appearance of the glaze. Under the magnifying glass, the glazes near the BaO apex contained somewhat smaller bubbles than those at the CaO or MgO apices. When fired under similar conditions in the periodic kiln the transparency of the glazes appeared to increase with the temperature. On the other hand, the number of open bubbles at the surface did not seem to depend upon either the temperature or the composition. It is interesting to note that the glazes fired in the Dressler tunnel kiln to cone 19 down in 31 hours were more opaque and smoother than those fired in periodic kilns to cone 16½ for 42 hours. The object of series B was to determine the effect on the appearance of the glaze of replacing Florida kaolin triaxially with Kentucky ball clay and N. Carolina kaolin. It was found that relatively little change was produced by this replacement. As was to be expected, the glazes containing all ball clay tended to overfire more readily than those made with kaolin or with a mixture of kaolin and ball clay. There was practically no difference in the colour of the glazes. As in series A, the glazes fired in the Dressler kiln were much superior. The best glazes with $0{\cdot}2\ K_2O$ and $0{\cdot}8$ CaO had an alumina-silica ratio of 1 : 9 and 1 : 11 for the field covered by series C. These glazes were generally more transparent than those with $0{\cdot}3\ K_2O$; otherwise the results were similar. The general conclusions drawn from the study are: (1) that the nature of the firing conditions is of the utmost importance in the development of a glaze; and (2) that an intelligent discrimination between glazes apparently of equal quality demands recourse to petrographic method and mechanical tests.

THE EFFECT OF SOME SUBSTITUTES FOR TIN OXIDE ON THE OPACITY OF WHITE ENAMELS FOR SHEET STEEL.—R. R. Danielson and M. K. Frehafer (*J. Amer. Cer. Soc.*, **6**, 634, 1923). Some of the commercial substitutes for tin oxide, together with others not in common use, were tested by the authors. A standard frit was used. The best substitutes were found to be zirconium oxide, and sodium antimonate; these rank very close to tin oxide. Zirconium silicate comes next, but the purity of this material is an important factor. Felspar opacifier (felspar 51·0, soda-ash 12·0, whiting 13·0, fluorspar 7·0, cryolite 9·0, sodium antimonate 8·0, ground in ball mill), zinc aluminate and "commercial substitute" are classed as fair. Opacity does not necessarily increase with the quantity of opacifier used; apparently an "overloading" is possible. The method developed by the Colorimetry Section of the Bureau of Standards for the accurate determination of the reflecting value is described. This involves the use of the spectrophotometer apparatus with illumination box, and the calculation of the total diffuse reflection from the spectrophotometric data.

COLOURS, DECORATIVE PROCESSES, ETC.

PHOTOGRAPHIC REPRODUCTIONS ON POTTERY.—(*Sprech.*, **53**, 483, 1923). Pigment paper containing ceramic colours, which can be handled in a manner similar to ordinary photographic pigment paper and used for the reproduction of photographs on ceramic ware, may be prepared as follows:

From 15 to 17 grams of hard gelatine are allowed to soften in 250 cc. of distilled water, and the gelatine is then dissolved by warming the mixture in the water bath; 15 gr. of white sugar are then added and carefully stirred up with the solution. From 8 to 10 grs. of iridium oxide are then triturated with 50 cc. of distilled water until the mixture is almost dry, whereupon the warm gelatine solution is added slowly and the whole triturated until the ingredients are thoroughly mixed and the mass assumes a semi-solid consistency. It is then transferred to a flask and heated over the water bath to restore it to the liquid state, filtered through flannel, and poured on to a smooth glass plate, which has been thoroughly cleaned. When the mass is again in a semi-solid state, a sheet of white absorbent paper must be spread carefully over the surface of the pigment, or the paper, which has been previously moistened, may be placed on the glass and the liquid pigment poured over it. Drying should take place in a drying cupboard or in a drying kiln with ventilation. To sensitize the pigment, the following solution is prepared: distilled water 500 cc.; pure spirit 200 cc.; potassium dichromate 15 gr. The paper should be dipped in this bath only sufficiently long to render it supple. An ordinary negative is used for copying and a photometer to control the exposure. After the exposure, the paper is softened in cold water and then applied to the ware. The paper must be made to adhere firmly to the ware by placing over it some suitable heavy object for half an hour. The whole piece is then submerged in warm water, after which the paper can easily be peeled off. The photograph must then be developed until the image appears clear and distinct. After development, the photograph is washed with spirit and dried. Finally, the whole of the decorated surface of the piece must be covered with a mixture containing 100 parts rectified oil of turpentine and 20 parts lavender oil, over which fine glass powder, or some similar flux, is spread. The ware is then ready to be fired. The firing process is, of course, a matter of practice; it can only be learned after lengthy experience.

PLANT AND MACHINERY, ETC.

A NEW "BATTING-OUT" MACHINE.—(*Cer. Ind.*, **1**, 135, 1923). The new machine described, which has been patented by F. Kinnard, will, it is claimed, eliminate the laborious "batting-out" process of preparing flat ware for the moulds. The Kinnard machine has a series of flat-faced paddles, the flat surfaces facing the workman. The "block" is of plaster of Paris, and is mounted on a hinged frame which can easily be raised to meet the series of rapidly revolving paddles. The machine is electrically driven. The operator takes the mass of clay, tosses it upon the block, and then raises the latter until the clay impinges against the revolving paddles, which roll out the clay into a disc of a much neater appearance and of more even thickness than could possibly be attained by the old "batting-out" method.

ON AUTOMATIC BRICK-CUTTING MACHINES.—(*Südd. Tonind.*, **5**, 56, 1923). A short, general survey is given of the development of brick-cutting machines. The three principal requirements of a really successful machine are: (1) the making of a straight cut; (2) steady and reliable working; (3) moderate cost. A machine satisfying all these conditions is not yet on the market.

WHEN MOTOR DRIVES ARE PREFERABLE IN BRICKWORKS.—(*Brick Pot. Tr. J.*, **31**, 167, 1923). The advantages of motor drives for machinery, where electricity is available, are enumerated.

ELECTRIC MOTORS IN BRICKWORKS.—(*Brick Pot. Tr. J.*, **31**, 138, 1923). Hints are given as to correct methods of bedding, structural supports, protection from moisture, dust, etc., gearing, drives, pulleys, etc.

THE JAW-CRUSHER AS A PRIMARY BREAKER.—C. G. Buchanan (*Rock Prod.*, **26**, No. 5, 75, 1923). Among general advantages of the jaw-crusher may be mentioned: (1) it is accessible in every part; (2) all moving or wearing parts can be adjusted or replaced quickly if necessary; (3) it has

a greater range of adjustment than the roll or gyratory crusher ; (4) the openings of the jaws can be increased or diminished.

PATENTS.

BRICK PRESSES.—W. H. Swanton and A. F. Echberg (*Pat. J.*, 1,817, 1923). No. 104,083. Relates to pressing plungers of stationary mould machines.

BALL MILLS ; PNEUMATIC SEPARATING.—J. E. Kennedy (*Pat. J.*, 1,817, 1923). No. 204,250, Dec. 18, 1922. Material such as rock, bone, coal, etc., is disintegrated in a revolving cylindrical drum, to which it is fed through one of the hollow supporting trunnions, the disintegrated material being withdrawn through the other by suction.

BRICK PRESS.—Etablissements C. Candlot, Soc. An. (*Pat. J.*, 1,818, 1923). No. 104,500, Sept. 5, 1922. Relates to hopper and plunger machines. The material is driven from a hopper, by a piston, into a compression chamber, each blow of the piston forming one brick.

MOULDING MACHINE.—Clay Cross Co., Ltd. and Mr. R. K. Bion (*Pat. J.*, 1,811, 1923). No. 202,164, Aug. 11, 1922. Brick-making apparatus is described in which a continuously-rotating table is provided to deliver the bricks from a pressing machine to a repressing machine.

PYROMETERS.—H. A. Daynes, Cambridge and Paul Instrument Co (*Pat. J.*, 1,813, 1923). No. 202,928, Apr. 25, 1923. To avoid errors due to variations in the cold-junction temperature of a thermo-couple, a pair of compensating leads are used, one of which at least is composed of a number of strands of wire of at least two different metals or alloys of suitable gauges

CYLINDER BRICK-MAKING MACHINES.—T. O. Partridge (*Pat. J.*, 1,816, 1923). No. 203,805. A method is shown of ejecting the bricks from the moulds on to an inclined, counter balanced platform, down which they slide to a conveyor. The moulds and plungers are heated by steam or electric coils

CUTTING ROOF TILES.—A. J. Winship (*Pat. J.*, 1,816, 1923). No 203,960, Nov. 17, 1922. A cutting machine is described.

SAGGAR SHORDS.—S. R., A. E. and T. D. Jackson (*Pat. J.*, 1,799, 1923). No. 197,889, Oct. 18, 1922. Illustrates a shord cast in aluminium, or aluminium alloy.

CRUSHERS WITH VIBRATING JAWS.—J. E. Kennedy (*Pat. J.*, 1,804, 1923). No. 199,670, Nov. 28i 1922.

BALL MILLS.—F. L. Smidth & Co. (*Pat. J.*, 1,805, 1923). No. 200,021, Nov. 8, 1922. In the ball, or tube mill described, one or more screening compartments, comprising a number of interconnected annular screening spaces, are arranged between the different grinding compartments.

MACHINE FOR MAKING JAM-POTS, ETC.—W. Ingram (*Pat. J.*, 1,807, 1923). No. 200,682, June 24, 1922. A machine is described for shaping jam-pots, etc. The traverse of the cutting tools is automatically regulated to suit varying diameters.

JIGGERS.—Dean & Lowe Ltd., and H. Howell (*Pat. J.*, 1,810, 1923). No. 201,750, 20 July, 1922. The upper end of the spindle is tapered and inserted in a socket, which it drives by a pin and slot. The socket rotates in a collar, the spherical exterior of which is clamped between two plates to the bench.

III.—FINISHED PRODUCTS: TESTING, ETC.

CAPPING FOR COMPRESSION SPECIMENS.—H. D. Foster (*J. Amer. Cer. Soc.*, **6**, 623, 1923). Compressive strength tests were made on tiles capped with (*a*) unretarded gypsum ; (*b*) neat Portland cement ; (*c*) a mixture of 3

parts by vol. of Portland cement to one part unretarded gypsum, and also on tiles the bearings of which had been ground. The last-mentioned treatment of the specimens gave the highest results. In view of the fact that it is impossible to grind the bearings of all types of tiles, cap (*c*) is advocated as giving the highest and most consistent results.

SOME NOTES ON THE MEASUREMENT OF TRANSLUCENCY OF CERAMIC BODIES.—C. W. Parmelee and R. E. Lowrance (*J. Amer. Cer. Soc.*, **6**, 630, 1923). The results obtained by previous investigators have been based upon the order of maximum thickness of the test-pieces employed, or, as in the case of Steger's recent work (*Ber. D.K. Ges*, **2**, 9, 1921), have been relative to certain standard pieces. In the present work, a photo-electric cell was employed, but results are not published, as the authors are engaged on rechecking them. The principle of the photo-electric cell is explained.

REFRACTORY FURNACE-LINING MATERIAL.—Hirsch (*Ker. Rund.*, **31**, 131, 1923). With the development of modern boiler construction, the demands made upon the refractory lining material in regard to mechanical strength, constancy of volume, refractoriness, and resistance to the action of slags have increased very considerably. In classifying firebricks, it is preferable to specify the nature of the raw materials employed, rather than to rely upon such uncertain descriptions as "acid" or "basic." In order to form a rough idea of the quality, it is usual to give the alumina-content and the refractoriness, but this is by no means sufficient. Judging by the specifications issued by various public bodies, it is now recognised that the external appearance, structure, alumina-content and refractoriness alone do not suffice to define the quality of a brick, but that, in addition, constancy of volume at high temperatures, resistance to changes of temperature, porosity, and, above all, resistance to the action of molten slag and fire dust must receive careful attention in selecting suitable lining material. Figures are given to show that refractoriness and alumina-content by no means coincide. The author reviews briefly the various properties required of bricks suitable for furnace linings. As regards *external appearances*, these bricks, should be free from cracks, have a good "ring," and firm edges and corners. The *structure* can best be determined by cutting through the brick with a saw and inspecting the cut surface through double-sighted magnifying apparatus. The so-called *refractory tests* do not give the actual melting-point in a physical sense, but merely a somewhat indefinite softening-point. According to the particular relationship between the silica and alumina contents, this point is frequently higher than the theoretical melting-point in the physical sense. This explains why the melting-point, expressed in Seger cones, depends very largely upon the method of testing, particularly upon the rate of the rise in temperature. Only results obtained by one and the same method can, therefore, be used for purposes of comparison. The mean value for *porosity* (water absorption) for this type of refractory lies between 13 and 15 per cent. of the dry weight. Little importance is now attached to the *cold crushing-strength*, in spite of the height of brick-work required for verticle tube boilers, since, as a rule, it bears no relation to the strength at high temperatures. The mean figure obtained from 100 tests on boiler-furnace bricks was 1892 lb. per sq. in. If no gaping cracks are visible in the brick, the author considers that a cold crushing-strength of 1,140 lb. per sq. in. would suffice. It is important that refractory bricks should not *shrink* excessively. The temperature in boiler furnaces usually varies between 1,100° and 1,300°C. But a change in volume is rarely noted on firing a brick to 1,300°, and tests are, therefore, carried up to 1,400°. Exceptionally good bricks exhibit a linear shrinkage of only 0·1 to 0·3 per cent., after repeated firings. The average figure can be taken as 0·5 to 1 per cent., although a shrinkage of 2 per cent. may be permitted. Special attention is now attached to *refractory-under-load* tests. The author briefly reviews the work of previous investigators and describes the apparatus in use at the Clay Industries Laboratory. Typical results are given in the following table. The tests were carried out

with a temperature rising slowing to 1,600°, or until the specimen commenced to collapse, the load applied being 28·5 lb. per sq. in. (2 kg. per sq. cm.)

	SiO_2	Al_2O_3	Fe_2O_3	Fluxes	Refractoriness	Softening commenced at	Collapse at	Linear shrinkage in m/m.
1	54·8	42·0	1·7	1·1	33	1210°	1380°	10·7
2	53·8	43·0	2·0	1·1	34	1240·	1500°	13·4
3	53·9	42·9	1·6	0·9	34+	1270°	1550°	15·2
4	51·9	46·3	1·4	0·1	35	1300°	1510°	11·7
5	86·0	11·6	0·4	1·8	27	1360°	1410°	2·5
6	61·3	34·6	2·0	1·6	33	1380°	1600°	12·3
7	50·3	46·7	1·9	0·6	35	1430°	1560°	9·0

This table shows the temperature at which softening commences, and also the point when collapse begins, *i.e.*, when actual cohesion ceases. At this point, the linear shrinkage is measured (the original length of the specimens is 50 mm.) It will be noted that the lowest softening-temperature is 1,210°, a very low figure, and this result was obtained with an apparently good-quality shale. On the whole, the shale bricks did not prove equal to the clay bricks, as represented by No. 5. The softening point and the temperature at which actual failure begins are not so adjacent with shale as with clay bricks; this is due to the fact that the latter, in their composition, more nearly approach the most fusible mixture of alumina and silica. The most essential property of refractory bricks for furnace linings is their ability to *resist the action of slags*. Slags vary considerably in chemical composition according to the type of fuel used. In order to test the effect of slags on bricks, without removing the outer, vitreous "fireskin," a ridge of highly refractory material is formed round the edge of the brick, forming a trough within which the powdered slag is placed, the whole being then fired to cone 14 in a works kiln. In general, the more dense the brick, the greater the resistance to slag attack. The destructive effect of slags, particularly those rich in lime, can also be counteracted by the application of suitable coatings. Tests were carried out on three bricks made from shale material, the first of which was unprotected, the second coated with corundum, and the third with silicon carbide. The protective effects of the coatings is shown by means of photographs. A fourth brick, made of dynamidon (a product prepared from fused alumina, containing 70% Al_2O_3), was not attacked in the least by the slag, though the latter was of a particularly corrosive type, containing much iron and lime.

THE MECHANICAL PROPERTIES OF REFRACTORIES AT HIGH TEMPERATURES.—(*Engineer and Iron Trades Advertiser*, **54**, 1923; Abs. in *Bull. Cleveland Inst.*, **2**, 687, 1623). Fusion and Seger cone tests by themselves have been shown by recent experimental work to be insufficient. The importance of crushing tests has been demonstrated by Le Châtelier and Bogitch. With silicon and alumina refractories, it was found that, as the temperature increases, the crushing-strength decreases gradually until, at about 1,000°C., there is a sudden increase followed by a gradual diminution up to the fusion-point. In some cases, this increase may amount to two or three times the crushing-strength at ordinary temperatures. On the other hand, chrome and magnesia refractories do not show any such increase in strength. A series of tests was carried out, with a carbon-electrode furnace, to verify the theory that part of the refractory was in a pasty state at about 1,000°, and further tests showed that the increase in strength is mainly a function of the rate of increase of loading. Considerable increase in the crushing-strength was noted when the load was increased at the rate of 23·75 to 300 lbs. per minute, whilst the viscous constituents yielded readily and without increase in strength when a constant load was applied for a

sufficient length of time. With felspathic kaolins, a second critical point was found at about 1,400°, and, on subsequent cooling, it was observed that vitrification had set in, preventing a recurrence of the phenomenon. It was shown that, in practice, static loading could alone give reliable results, whilst rapid increase of loading gives illusory data.

SOLVING FURNACE LINING PROBLEMS.—C. E. Nesbitt and L. M. Bell (*Iron Trades Rev.*, **72**, 1,603, 1923). The paper gives the results of laboratory tests conducted on fire bricks for blast furnaces to determine the cause and prevention of disintegration. Disintegration in furnace linings has been found to be greatest at about 40 to 50 feet from the top of the furnace, and it appears to be more prevalent to-day than it was 15 or 20 years ago. Numerous investigators, including Sir Lowthian Bell, and B. Osann, have studied disintegration of refractories and the action of carbon monoxide in iron blast furnaces, and various explanations have been advanced to account for the phenomena observed. Bell found that ferric oxide was deoxidised by carbon monoxide, accompanied by a deposition of carbon at all temperatures between 150°C. and a bright red heat, the reaction reaching its maximum strength about 417°. Osann found that carbon was deposited when iron ores were subjected to carbon monoxide between 430 and 500°. Disintegration has also been attributed to the presence of zinc and lead, or their oxides, in the bricks, but apparently these metals do not of themselves cause failure of the bricks by disintegration. Again, the presence of alkalies has been suggested as a cause of disintegration, but bricks taken from used linings have shown more than 10 per cent. of alkalies, and yet have been intact. Figures are tabulated to show that the chemical composition of furnace bricks undoubtedly changes in service. On the other hand, analyses of bricks from the centre, or cooler, zone showed little sign of chemical change, yet examination indicated that they were disintegrated. The lining of a furnace, which had been run on ferro-alloys for 16 months, was also examined and found to be disintegrated from top to bottom. The carbon monoxide in this furnace was 50 per cent. higher than in an iron furnace, and it was, therefore, assumed that the degree of concentration of the CO had an important bearing on the rate of disintegration. The laboratory tests were begun by passing carbon monoxide over ferric oxide in glass test tubes. The greatest carbon deposits were obtained by slowly raising and lowering the temperatures between 420 and 470°C. By this means carbon deposits were built up on small amounts of iron ore during a 10-hour exposure, until the resulting volume was approximately 70 times that of the original ore. In the reaction the ferric oxide appears to be reduced to a lower oxide, or possibly spongy metallic iron, and the reduced product acts as a catalyser, breaking up the carbon monoxide according to the reaction: $2CO = CO_2 + C$. The method of testing full-size bricks was as follows: A rectangular cast iron box, sufficiently large to hold twelve 9-inch bricks, was equipped with a close-fitting cover. Gas was introduced through a pipe at the upper corner and led off at the lower corner diametrically opposite. The sealed box was heated uniformly in a gas-fired furnace while carbon monoxide was being passed through. Special bricks were prepared with two first-quality clays, free from visible iron, various percentages of iron in the form of ore, ferric oxide, or pyrites being added to the mix. The bricks were moulded by hand, dried, and fired. The burned bricks of each kind were then subjected to carbon monoxide for 10 hours at 420 to 450°C. In the iron ore series, a slight cracking was noted in the bricks containing 0·25 per cent. and a marked increase in disintegration with increasing percentages of ore, the last of the series, containing 2 per cent. of ore, being badly shattered. The bricks containing 1½ per cent. of pure ferric oxide and those with the same quantity of pyrites failed in the same manner as those containing the corresponding amount of ore. Test bricks made from the selected clays without the addition of iron showed no disintegration after 36 hours exposure, while ordinary commercial bricks placed alongside them failed completely in 10 hours. *Size of Impregnations.*

A series of bricks was prepared by adding one per cent. of iron ore which (*a*) passed a 100-mesh sieve; (*b*) remained on an 8-mesh. After exposure for 10 hours to carbon monoxide at 450°, the bricks with the fine ore addition showed only small surface cracks and little change in appearance except a darker colour, while the coarse ore bricks failed by developing long irregular cracks. Heavy deposits of carbon were found round the large iron spots, and in many cases cracks were observed radiating from these deposits. *Effect of Burn.*—Preliminary work indicated that soft burned bricks disintegrated more quickly than hard-burned. Experimental bricks were made with a first-quality clay and an addition of 2 per cent. of finely-ground iron ore. After drying, some of the bricks were left unburned, others were fired to 1,050°, and the remainder to 1,300°C. The bricks were then exposed to carbon monoxide at 450°. All the bricks burned at 1,050° failed from disintegration, while the unburned, and those fired to 1,300° were only slightly affected. The fact that unburned bricks were but slightly affected was also demonstrated by additional tests; it was noted, for instance, that fireclay mortar, to which 2 per cent. of iron oxide had been added, was only slightly disintegrated round the iron spots. *Effect of Methods of Manufacture.*—The manner in which bricks are made has a considerable influence on the ease with which they disintegrate. Augur-made bricks, being laminated, fractured along the lines of weakness. Steam-pressed bricks usually failed by splitting length-wise, while hand-made bricks fractured irregularly. Furthermore, the finely-ground bricks were found to disintegrate to a slightly greater extent than the more coarsely-ground. *Conclusions.* To prevent disintegration effectively the bricks must be free from uncombined iron oxide. Only clays free from these compounds should be used, and provision should be made for purifying them. The practice of taking the clay direct from the mine should be abandoned. Since washing, screening and grinding are not practicable, the only suitable remedy is weathering. The clay should be spread out in layers of not more than two feet in thickness for at least two months, moisture being added from time to time if the weather is dry. This treatment will oxidise the iron compounds, which will change to a brown or yellow colour. Such lumps, or patches, must then be discarded and only the unstained clay should be used. A *medium burn* is all that is permissible in a blast furnace brick, for, although a hard burn will reduce its sensitiveness to disintegration, it will, at the same time, increase its susceptibility to rapid changes of temperature.

IV.—MANAGEMENT, ORGANISATION, COSTING, ETC: COMMERCIAL.

LABORATORY CONTROL AT THE CHAMPION PORCELAIN COMPANY'S WORKS.—(*Cer. Ind.*, **1**, 182, 1923). At the plant of the Champion Porcelain Co., at Detroit, each factory operation has its counterpart in the research laboratories of the Company, which manufactures sparking-plug porcelain exclusively. Complete control is exercised throughout the plant, from the inspection and testing of raw materials to the final testing of the porcelain. In-coming raw materials are sampled and regular firing, screening and fusion tests are made. The latter tests are made in a small surface combustion pot surface, capable of reaching cone 35 in less than an hour. A completely equipped chemical laboratory furnishes analyses whenever required. Shrinkage is determined by means of a mercury volumeter, and a delicate Jolly balance is employed for apparent specific gravities. Control does not cease after the body has been made up and released. Each batch of body as made, receives a number, and in each saggar of ware are two pieces, the tips of which are coloured and on which this batch number is marked. One of these pieces is actually broken after firing to examine for underfiring, while the other is sent to the laboratory for a thorough testing. An apparatus has been recently developed, and is now in actual operation, for

automatically controlling the temperature of the Dressler kiln to any desired temperature. This apparatus automatically takes care of all changes in the quality and pressure of the gas, the temperature of the air supplied to the kiln, etc., and maintains the temperature of the kiln constant within a few degrees. Gauges measure the cooling water temperature at the outlet, the gas pressure, the gas booster pressure, the gas pressure at the kiln, the cooling fan vacuum, the current consumption of the pusher, and duplicate, 24-hour pyrometer recording charts are installed in the laboratory, where records are kept. An operator in the laboratory can notify the kiln foreman at once of any serious divergence from the normal of any chart. In addition, there is, in the laboratory, a continuous daily chart, showing the location of every batch in production and its location in every department, from the time it is milled until it is out of the kiln. This is found invaluable in following production and in issuing firing orders to the kiln foreman, based upon the results of the preliminary saggars. Several routine tests, formerly made in the research laboratory, are now carried out in the production laboratory, and it is intended from time to time, as standards are definitely set up for various operations, to transfer the control to the production laboratory, thus leaving the research laboratory more free for pure research. The article is well illustrated.

PORCELAIN MANUFACTURE IN INDO-CHINA.—(*Can. Chem. Met.*, **7**, 59, 1923). The beginning of a national porcelain industry at Tonkin, is announced. Indo-China itself will be the principal sales outlet. The local Government is supporting the venture.

POTTERY MAKING ON THE BLUE NILE.—(*Can. Chem. Met.*, **7**, 72, 1923). Writing on the Blue Nile Pottery industry, H. A. Macmichael describes the manufacture of the "Burma," or pots for carrying and storing water, and the "Sagias," or water-wheels. The implements used are a smooth piece of stone resembling a penny bun in shape and size, and an oblong, slightly concave river shell. With these the clay is kneaded with donkey's dung, beaten into shape, and smoothed.

SOME NOVEL FEATURES IN POTTERY MANAGEMENT AND EQUIPMENT —(*Cer. Ind.*, **1**, 336, 1923). A description is given of the plant which the Onondaga Pottery Co. has recently constructed for the manufacture of hotel and domestic china at Syracuse, N.Y. The works were laid out on the basis of two fundamental ideas, the first being the implied, or unasserted supervision of labour, and the second the mobility of operators and equipment. With regard to the first of these two factors, it was recognised that, in order to give the management adequate opportunities of supervision, the factory must be built with large open rooms with no dark corners or alleys to tempt the workers to "slack" at their duties. Great care is taken in the selection of workmen, the best prospective persons only are acceptable. An apprentice school is now being inaugurated, classes of some 20 students receiving instruction under an experienced trained teacher. It is intended that this school shall be a permanent institution at the works to provide a source of supply of trained workers. The usual social facilities, amusements, etc., are provided, and, in accordance with modern practice, the company has its own doctor and nurse.

The second factor, that of mobility, depended largely upon the industrial lift truck as its basis. At present, there are 32 specially designed lift trucks in use on the new plant and this number is being increased. These trucks have rubber tyres and they were developed after much study of the requirements of a pottery of the Onondaga type. In addition, much of the equipment, which on the average works is ordinarily found stationary, is mounted on wheels so that it can be moved about. This mobility of apparatus and equipment is the main theme of production in the new plant. The single story, monitor type of building was held to be best suited to enable the plans to be carried out. The raw materials are unloaded into truck-tractors, which convey them up an inclined runaway over the roof of the building. They are then

dropped through the roof directly into the bins beneath. The clay cellars are not located below the operating floor, but on the same level. There are two cellars measuring about 10 by 20 ft. and they are lined with slate. Exposed concrete is regarded as objectionable; consequently, no concrete can be seen anywhere throughout the plant. The shop floors are of maple with a concrete support, and the flooring is laid in the direction of the movement of materials. Another unusual feature is the portable pug mill. This, together with its motor and transmission, is mounted on a truck in a single unit, and so can be moved at will. The pug-mill is, therefore, taken to the work instead of the work being taken to the pug-mill. All the pugging machines are mobile. Each machine, together with a motor and the bench, is fastened to a table set on trucks. The machine can thus be moved about at will and placed to suit the convenience of the operator. Each potter has his own stove room and individual heating control system. By this means, the number of steps required in handling the product and in placing the ware in the dryers is reduced to a considerable extent. The ware leaving the dryers is placed on specially constructed racks designed to be conveyed by a lift truck. After inspection, the ware is stacked and placed upon a special machine, which, in the case of plates, pours a mixture of raw ground clay and ground burned clay into the spaces between the plates. This prevents warping. These stacks are then placed on similar racks and removed to the green ware storage room, which has several sections, one for each kiln, between the finishing and the saggar loading departments. Each section holds just sufficient ware to charge a kiln. When the room has been filled by the finishing department, it is locked at that end and remains locked. The kiln loading department then draws the ware from the other end. In this way a complete check is possible upon the quantity of ware loaded. The system also enables checking of losses.

The kilns are of the round, down-draught type of 17′ 6″ diameter, and 16′ high to the crown. They hold approximately 3,600 to 3,700 dozen of ware. To clean the biscuit ware of the ground clay placed between the layers of plates, a sand blast machine is employed. The sand and clay are separated, and the burned clay is ground and utilised again in the green room. A long corridor over a thousand feet in length, runs through the entire factory, doorways leading from it to the various departments. This corridor was built to avoid the passing of dirt from one room into another, and it is claimed that, as a result, the small black specks in the ware, which are so troublesome on potteries have been reduced considerably. A special two-storey building houses the plant laboratory, which will enable the factory to maintain absolute control over its products. The costing system, which has been developed at the Onondaga pottery after a thorough investigation, is regarded by the management as one of the most valuable assets of the company. As a result of the development of the system, it was found that many of the lines produced were being sold at a loss, whilst others were selling at large profits. For example, of 259 articles upon which costs were computed, 192 were found to be bringing in profits, ranging from 1 to 60 per cent, while the remaining 67 items showed losses of from 1 to 89 per cent. on the sales price. The costing system thus enabled the firm to reprice its ware, so that a reasonable profit was made on all lines.

THE ORGANISATION OF A DECORATIVE CERAMIC RESEARCH DEPARTMENT.—F. H. Rhead (*J. Amer. Cer. Soc.*, **5**, 758, 1922). The typical art pottery organisation is described and the research program in relation to losses is discussed. The types of losses are classified.

IS ELECTRICITY BEST FOR BRICKWORKS?—(*Brick Pot. Tr. J.*, **31**, 132, 1923). Electricity has the advantage when a shale or other dry clay is being treated, but in the case of wet or plastic clays, necessitating drying, steam is almost imperative.

CUSTOMS, TARIFFS AND CERAMIC PRODUCTION IN ITALY.—(*Corr. Cer.*, **4**, 93, 1923). The writer maintains that the scarcity of fuel

and raw materials in Italy renders imperative the maintenance of the July, 1921, tariffs.

ELIMINATING THE WASTE OF HUMAN EFFORT.—L. B. Hopkins (*Ind. Man.*, **10**, 150, 1923). The importance of proper selection, and of the failure of management to recognise the value of training, transfer and promotion is pointed out.

THE IMPORTANCE OF ELUTRIATION TESTS IN CERAMIC PRACTICE.—(*Ker. Rund.*, **31**, 360, 1923). The Schöne apparatus is described and illustrated, and the general advantages derived from the use of such an apparatus are indicated.

V.—GLASS : GENERAL.

THE PLATE-GLASS GROUP.—E. Zschimmer (*Sprech.*, **56**, 239, 1923). A synopsis of the literature dealing with glasses of the "plate" type, containing sodium, potassium, lime and silica in varying proportions, is given. A list is appended showing the composition of 249 industrial glasses.

MECHANICAL DRAWING OF SHEET GLASS.—J. Scory (*Génie Civil*, **82**, 603, 1923). A brief review of modern methods. The Fourcault system is described and illustrated.

"DUROSIL."—(*Gas J.*, **164**, 312, 1923). A short account is given of the properties and uses of Durosil, manufactured by Duroglass Ltd. The glass is highly resistant to thermal shock and to the action of acids and alkalis. It is now being made into domestic utensils.

DECORATIVE PAINTING ON GLASS.—M. de Keghel (*Rev. Prod. Chim.*, **26**, 645, 1923). A series of articles giving a detailed account of the technique.

DECORATIVE PAINTING ON GLASS.—M. de Keghel (*Rev. Prod. Chim.*, **27**, 1, 1924). Continuation of above, dealing with mixing and colour harmony.

SOME NOTES ON THE EARLY HISTORY OF CUTTING AND ENGRAVING GLASS IN ENGLAND.—F. Buckley (*Glass*, **1**, 59, 1924).

NOTES ON GLASSWORKS FURNACES IN BRITISH FACTORIES.—Th. Teisen (*Glass*, **1**, 61, 1924). The furnaces most commonly used in making pressed glass, table and fancy glass, bottle ware, etc., are discussed, and comparisons are made with continental practice. The article closes with a short note on refractories.

THE MAKING OF BOTTLES.—(*Glass*, **1**, 79, 1924). A well-illustrated description of the Chorlton Works of the United Glass Bottle Manufacturers Ltd., "Europe's largest glass bottle factory," is given.

THE USE OF DOLOMITE IN GLASS MAKING.—(*Glass*, **1**, 91, 1924). The work of the research associations has shown that magnesia is not a dileterious ingredient, but may be added to the batch with advantage. Warmsworth dolomite contains : 0·09% silica, 0·12% alumina, 0·15% iron oxide, 0·05% manganous oxide, 31·3% lime, 20·46% magnesia. Substituting dolomite for limespar in a typical colourless batch, the amount of iron in the resulting glass is 0·0856%.

THE NEW GLASS RESEARCH DEPARTMENT AT SHEFFIELD.—(*Pot. Gaz.*, **49**, 123, 1924). An illustrated description is given of the extended premises of the Glass Technology Department of Sheffield University.

RAW MATERIALS USED IN THE MANUFACTURE OF GLASS.—C. J. Peddle (*Glass*, **1**, 52, 1924). Raw materials are divided into 5 classes : (1) refractories (sand, felspar and clay) ; (2) fluxes ; (3) colouring materials ; (4) opacifiers, and (5) decolorisers. The effect of iron upon colour is discussed. The most important raw material is sand, which comprises some 70% of all glass. A good sand should (1) be of even grain size ; (2) have a high silica

and (3) low iron content, and (4) be free as far as possible from alumina, lime, magnesia and alkalies. An ideal sand would have all its particles of 0·25 mm. diameter. The value of washing is strongly emphasised and is illustrated by micro-photographs. Washing tends to eliminate the finer portions, which contain much iron and other impurities.

PREPARATION OF FUSED SILICA.—(*Chem. Age*, **10**, 116, 1924; *Chem. Tr. J.*, **74**, 153, 1924). A brief report of a lecture by R. A. S. Paget on "The History, Development and Commercial Uses of Fused Silica." Brief notes on the discovery of practical methods are included.

NOTE ON THE ACTION OF POTASSIUM CARBONATE ON LEAD GLASS.—E. A. Coad-Pryor (*J. Soc. Chem. Ind.*, **43**, 27T, 1924). The need for a simple standard test for the suitability of a glass for any particular purpose is brought into prominence by experiments recently described by H. D. Richmond (*Analyst*, **48**, 260, 1923). The author analysed a sample of the glass used by R. with the following result:—SiO_2 67·30%, PbO 13·25%, CaO 2·30%, Al_2O_3 trace, alkali 17·00%, As_2O_3 0·34%,—a most unsuitable glass for storing potassium carbonate. Figures are given to show that there is no objection to the use of lead in these glasses. Tests for resistance to chemical reagents on a heavy lead glass (40% PbO) and on Jena glass showed that the former was the better of the two. The alkali content should be below 16%. A promising test appears to be that described by Blackmore Dimbleby & Turner (*J. Soc. Glass Tech.*, **7**, 122, 1923), which consists in exposing the glass to the action of narcotine hydrochloride at 100°C. for not more than one hour.

PATENTS.

DELIVERING MOLTEN METAL.—W. J. Miller (*Pat. J.*, 1,812, 1923). No. 202,610, Mar. 12, 1923. Delivering apparatus is described at some length.

CUTTING GLASS.—C. Zeiss (*Pat. J.*, 1,812, 1923). No. 202,627, Aug. 7, 1923. Relates to machines for cutting non-circular glass. Addition to *Spec.* 154,577.

TANK FURNACE CONSTRUCTION.—Soc. Anon. Brevets Fourcault (*Pat. J.*, 1,814, 1923). No. 203,260, Dec. 22, 1922. In a tank furnace for the manufacture of sheet glass having apertures formed by depending bridges, a homogeneous block of refractory material constitutes the lower portion of each bridge, so that the usual irregular corrosion of the bridge is avoided.

GLASS MOULD-OPERATING DEVICE.—J. L. Pagés (*Pat. J.*, 1,815, 1923). No. 203,596, Dec. 9, 1922. The device consists of a hinged platform connected by a toothed section with a shaft on which the mould is mounted, so that the mould is raised out of the water into the blowing position when the blower steps on the platform.

SHEET-DRAWING APPARATUS.—Libbey-Owens Sheet Glass Co. (*Pat. J.*, 1,809, 1923). No. 201,429, Aug. 23, 1922. A modification of *Spec.* 114,977, in which the grippers for pressing the edges of the sheet against the moving drawing table are replaced by positively-driven rollers.

SHEET-DRAWING APPARATUS.—Libbey-Owens Sheet Glass Co. (*Pat. J.*, 1,809, 1923). No. 201,444, Sept. 16, 1922. Additional to *Spec.* 114,977, and provides for the removal of the bending-roller when tarnished without nterrupting the production of plate glass.

DELIVERING MOLTEN METAL.—C. H. Rankin (*Pat. J.*, 1,812, 1923). No. 202,496, July 26, 1922. In a feeding-device, comprising a throat-block and a nose cup, with ducts or gutters arranged therein to deliver the glass in separate streams, adjustable gates or plugs are provided in the ducts to regulate the flow of glass.

DRAWING SHEET GLASS.—Soc. Anon. Brevets Fourcault (*Pat. J.*,

1812, 1923). No. 202,576, Dec. 22, 1922. A modification of the Fourcault process. The slot through which the sheet is drawn is kept at uniform width as before, but the mass in the block is made broader at each end.

PRODUCTION OF PLATE GLASS FREE OF STRIÆ.—C. E. Huard (*Pat. J.*, 1,826, 1924). No. 207,195, Nov. 16, 1923. The metal is first fully melted and refined in a pot furnace and then transferred by a channel to a tank furnace, from which it is gathered or drawn. The channel is jacketed by a flue to prevent the metal from chilling.

ROLLING GLASS SHEETS.—Chance Bros. & Co. Ltd., and A. L. Forster (*Pat. J.*, 1,827, 1924). No. 207,384, Dec. 5, 1922. The invention, as applied to a rolling machine, comprises rotatable cutting tools, movable transversely to the glass delivered by the machine, and also means for carrying the tools forward with the glass during the cutting operation.

FORMING SILICA-GLASS ARTICLES.—General Electric Co. (*Pat. J.*, 1,827, 1924). No. 207,457, Mar. 16, 1923. The method consists in exerting moulding pressure on the fused quartz, while it is plastic, by the expansion which takes place when the quartz passes from one modification to another of lower density. A suitable mould is packed with pieces of quartz and heated in a furnace to about 1,650°C. at which temp. the quartz expands and fills the mould.

TANK FURNACE.—Soc. Anon. Brevets Fourcault (*Pat. J.*, 1,820 1923). No. 205,404, Dec. 22, 1922. An arrangement is shown for maintaining the necessary even temperature, by means of hollow walls, etc., in a tank furnace having a series of drawing apertures with intervening chambers.

BOTTLE-BLOWING MACHINE.—L. V. Lockwood (*Pat. J.*, 1,821, 1923) Nos. 205,736-8, Dec. 14, 1922.

GLASS CYLINDER DRAWING.—W. L. Munro (*Pat. J.*, 1,821, 1923). No. 205,766, Mar. 29, 1923. Relates to apparatus described in *Sped.* 141,791. The modification consists in arranging the venting chamber adjacent to the bait, instead of being connected to it by a long tube.

DRAWING SHEETS.—Soc. Anon. Brevets Fourcault (*Pat. J.*, 1,821, 1923). No. 205,779, Dec. 22, 1922. Sheets are drawn from gas-tight compartments formed in the tank by bridges and walls. Cooling of the metal near the walls is counteracted by means of gas flames, admitted through ports in the crown of the tank.

DELIVERING MOLTEN METAL.—C. W. Plenkharp and H. Raynes (*Pat. J.*, 1,816, 1923). No. 203,858, July 28, 1923. The delivery device is so arranged that the molten glass can be supplied from a single aperture to any one of a number of stations.

DELIVERING MOLTEN GLASS.—Hartford-Empire Co. (*Pat. J.*, 1,819, 1923). No. 205,033, June 11, 1923. Relates to the method of feeding charges of molten glass through a submurged outlet (*Spec.* 194,675 and 195,376). According to the invention, the fluid pressure is allowed to force the glass back against a resistance, which is less than that retarding the outflow of the glass.

LIGHT FILTERS.—F. E. Lamplough (*Pat. J.*, 1820, 1,923). No. 205,381, No. 29, 1922. A light filter for producing daylight effects from artificial sources of illumination consists of a glass containing gold in addition to copper and one or more of the ingredients cobaclt, lnkel, or manganese.

VI.—CEMENT, CONCRETE, MORTARS, ETC.

CEMENT RESEARCH IN GERMANY.—R. W. Scherer (*Rock Prod.*, **26**, No. 6, 21, 1923). The paper gives an abstract of the Proceedings of the German Association of Portland Cement Manufacturers. The subjects discussed

include: Thermo-chemical manifestations during the burning process; Does cement crystallize? Potash recovery; Revision of German standards for Portland cement; investigation of concrete and re-inforced concrete.

FIRE RESISTANCE OF CONCRETE PROTECTED AND REINFORCED CONCRETE BUILDING COLUMNS.—S. H. Ingberg (*Rock Prod.*, **26**, No. 5, 120, 1923). The results of two series of fire tests, carried out during the past 5 years, are given. There are numerous illustrations.

STONE SCREENINGS AS FINE AGGREGATE FOR CONCRETE.—D. A. Abrams (*Rock Prod.*, **26**, No. 5, 131, 1923). Four separate series of investigations in which comparisons were made between the relative merits of natural sands and screenings, were carried out. The results, which are tabulated, apply only to the strength of the resulting mortar or concrete.

TESTS ON REINFORCED CONCRETE MADE WITH CEMENT POWDER.—G. Leflot (*Génie Civil*, **83**, 126, 1923). Results are given of tests conducted by the Conservatoire national des Arts et Métiers.

PATENTS.

ARTIFICIAL STONE.—Glasfabriek Leerdam (*Pat. J.*, 1,810, 1923). No. 201,880, Feb. 7, 1923. The composition, which is suitable for making paving blocks, vases, and pots, consists of a vitreous mass containing undissolved sand. The usual raw materials of glass manufacture with excess of sand may be used, or old glass may be pulverised and mixed with sand. Colouring agents and cheap waste materials, such as "sinters," bone-meal, kaolin, manganese, and cobalt may be added.

MOULDING CONCRETE POSTS, ETC.—P. C. Cannon and Centrifugal Concrete Blocks and Poles Ltd. (*Pat. J.*, 1,813, 1923). No. 202,742, May 26, 1922. A method and a machine are described, by means of which relatively long hollow objects are formed in a mould and rotated.

POROUS BUILDING MATERIALS.—E. C. Bayer (*Pat. J.*, 1,816, 1923). No. 203,718, Sept. 11, 1923. Cements, plaster, etc., are rendered porous by the addition of a foam-developing substance and the injection of gas under pressure during mixing.

SLAG CEMENT.—W. K. Cochrane (*Pat. J.*, 1,816, 1923). No. 203,963, Nov. 23, 1923. A mixture of blast furnace slag and calcium carbonate in suitable proportions is crushed or stamped by machinery so as to reduce the slag to an amorphous powder. The ground mixture is washed with water to remove soluble impurities, *e.g.*, calcium sulphide, and the resulting slurry is calcined and ground in the usual manner.

CONCRETE MIXING MACHINE.—G. Jaeger (*Pat. J.*, 1,817, 1923). No. 204,224, Oct. 16, 1922. In the machine described, means are provided for delivering a predetermined quantity of water to the mixing drum for each batch.

MOULDING CONCRETE BLOCKS.—W. H. Smith (*Pat. J.*, 1,888, 1923). No. 204,414, July 1, 1922. Relates to stationary mould machines. The mould bottom is operated by double toggle mechanism, one toggle compressing the material, the other ejecting the moulded block.

VII.—CHEMICAL AND ANALYTICAL PROCESSES.

THE ANALYSIS OF TITANIUM PIGMENTS.—L. E. Barton (*Chem. Tr. J.*, **72**, 357, 1923). Simplified volumetric and gravimetric methods are given

THE LAW OF DISTRIBUTION OF PARTICLES IN COLLOIDAL SUSPENSIONS, WITH SPECIAL REFERENCE TO PERRIN'S INVESTIGATIONS, PART II.—A. W. Porter and J. J. Hedges (*Trans. Faraday, Soc.*, **19**, 1, 1923).

ON THE RELATION BETWEEN SURFACE TENSION AND DENSITY.—D. B. Macleod (*Trans. Faraday Soc.*, **19**, 38, 1923).

DETERMINATION OF SIZE AND DISTRIBUTION OF SIZE OF PARTICLE BY CENTRIFUGAL METHODS.—The Svedberg and J. B. Nichols (*J. Amer. Chem. Soc.*, **45**, 2,910, 1923). A method of applying a modified form of Stokes' law, which gives an exact formula for determining the radius of a particle sedimenting under centrifugal force, is described. A description is given of a special type of centrifuge, by means of which a sol may be observed or photographed while it is being precipitated. The method depends upon the projection of a uniform beam of light up through the tube containing the material each time the tube passes over a certain point. The rate of movement of the particles in the tube may then be observed. Results are given for two different gold sols, clay, barium, sulphate, and arsenious sulphide. Another method for the determination of the size of particles, depending upon the variation of concentration with distance from the axis of rotation in a disperse system subject to centrifugal force, is also discussed.

THE RELATION OF HYDROGEN-ION CONCENTRATION TO THE FLOCCULATION OF A COLLOIDAL CLAY.—R. Bradfield (*J. Amer. Chem. Soc.*, **45**, 1,243, 1923). The effect of varying hydrogen-ion concentrations upon the electrolyte requirement of soil colloids was studied by the author. The data presented indicate that, when phosphate salts are used with colloidal clay, certain differences are encountered which seem to be due to the specific action of the phosphate ion, and not to variations in the hydrogen-ion concentration. Hydrochloric, sulphuric, phosphoric and acetic acids flocculated clay at about the same Sörensen value, but greater acidity was required with citric acid. Changes in Sörensen value from 6·2 to 8 increased the electrolyte requirement tenfold in the case of mixtures of potassium chloride and hydroxide. Further increases in alkalinity were without effect. Dipotassium phosphate mixtures showed a similar variation in flocculating power with changes in hydrogen-ion concentration. The phosphate curves differ, however, from the chloride curves in three respects: (1) The break occurs in more acid mixtures; (2) the electrolyte requirement is higher; (3) the curve shows a second minimum in alkaline mixtures. The results indicate that the flocculating power of potassium salts is influenced by the nature of the anion even when compared at the same Sörensen values. Secondary reactions seem to be responsible.

VIII.—HISTORICAL, EDUCATIONAL INSTITUTIONS, ETC.

THREE CENTURIES OF CHINESE POTTERY.—(*Pot. Glass Rec.*, **5**, 497, 1923). A short discussion of R. L. Hodson's book: "The Wares of the Ming Dynasty."

WHO DISCOVERED HARD PORCELAIN IN EUROPE?—(*Ker. Rund.*, **31**, 341, 1923). The question is discussed by Prof. Rudolph, foot notes being added by Dr. Heintze. The former states that German hard porcelain owes its origin to E. W. v. Tschirnhaus (1651-1708), while the latter upholds the claim of J. F. Boettger (1682-1719).

ROOKWOOD POTTERY, CINCINNATI.—(*Claywr.*, **81**, 24, 1924) An illustrated description is given of the works, at which art-ware only is produced. The artists are allowed full freedom to develop individual tastes The decorations are made on the moist clay before firing, the colours being mixed with clay, and becoming part of the ware itself.

OLD AND NEW AT ETRURIA.—(*Pot. Gaz.*, **49**, 106, 1924). The progress being made in modernising the famous Wedgwood works is illustrated

THE CZECHO-SLOVAKIAN CERAMIC SOCIETY.—(*Allgem-Tonind. Ztg.*, **42**, No. 50, 1923). The inaugural meeting of this Society, at which various

government departments, industrial associations, chambers of commerce, technical institutions, etc. were represented, was held on December, 11th, 1923. In a speech, in which he outlined the aims of the new Society, Prof. Dr. Kallauner stated that their main objects would be to keep the members informed of all progress made in the different branches of the industry, both at home and abroad, and to publish regularly the results of original work of members, committees, etc.

POTTERS' "ASTHMA,"—R. Franz (*Ker. Rund.*, **31**, 149, 1923). The term "asthma" is often applied by the layman not only to the disease itself in the strict medical sense, but also to all sickness, the symptoms of which are congestion of the lungs, respiratory troubles, etc.; yet these symptoms are by no means characteristic of any one malady. They occur in a number of fundamentally different diseases, and they indicate simply that, for some reason or reasons, the work of the lungs, in effecting an interchange of gases, is not functioning freely. This happens in particular when, as is the case with inflammation and contagious diseases, part of the lungs is filled with inflammatory exudates, so that the absorption of oxygen and the emission of carbon dioxide (*i.e.*, the normal function of the lungs) cannot proceed to the full extent (*e.g.*, pneumonia, tubercolosis, bronchitis, bronchial catarrh, etc.) The same symptoms appear when the capacity of the lungs is decreased through the inhalation of foreign matter (dust, etc.). It is important to note, however, that these symptoms are not necessarily the result of pulmonary disease, *i.e.*, of the respiratory organs themselves; they may also be due to heart trouble. Heart disease is frequently accompanied by an accumulation of blood in the lungs, whilst a weak heart is incapable of properly transporting the oxygen absorbed by the blood in the lungs and distributing it to all parts of the body. And this does not exhaust all the possibilities.

The inhalation of dust is, naturally, looked upon as the chief cause of pulmonary trouble in potters' shops. Fortunately, a very large proportion of the dust inhaled is caught in the nasal passages and upper air tubes; but it must not be forgotten that, during the normal eighteen breaths per minute, nine litres of air pass through the lungs; in an eight-hour day, therefore, approximately $4\frac{1}{2}$ cubic metres. Even if it is assumed that only one per cent. of the dust actually penetrates into the lungs, it is obvious that this must amount to a considerable quantity if the workman is compelled to work for months, and even years, in a dust-laden atmosphere. The dust in potters' shops is particularly harmful owing to the fact that the fine particles are almost insoluble in the body juices, so that they remain lodged in the lungs or adjacent tissues; furthermore, their sharp edges may cause serious injury to the tender lung tissues, setting up inflammation and thus providing suitable ground where bacteria may lodge and thrive. In short, a whole series of pathalogical symptoms appear in the lungs. The breathing capacity of the lungs is also reduced, partly by the inhaled dust, and partly by the inflammation caused thereby, and thus the so-called asthmatical symptons (difficulty in breathing) make their appearance.

The manner in which the disease contracted suggests the obvious remedy: all dust should, as far as possible, be prevented, or removed, by mechanical or other means. Preventive measures are of the greatest importance, for, when once the mineral matter has penetrated into the lungs, no treatment can possibly remove it. Although the dust particles may be gradually absorbed by the phagoxytes in the body and deposited in lymph glands and other less vital tissues, yet this reparatory process is of long duration, and even then endurated and atrophied lobules of the lungs are left behind as a result of the injury.

It has repeatedly been observed that men occupied in preparing the moist clay are subject to heart trouble, due to the peculiar and relatively strenuous nature of their work. This again leads to respiratory disturbances. Wherever possible, therefore, the aid of mechanical means should be called in as a preventive measure, for, as in the above-mentioned instance, a real cure

can only with great difficulty be effected when once the muscles of the heart have become seriously affected.

It is improbable that lead poisoning plays any important part in the geneses of asthmatical symptoms. In any case, diagnosis is simple; microscopical examination of the patient's blood will readily show whether the changes in the red blood corpuscles, characteristic of lead poisoning, have taken place.

RESEARCH IN THE U.S.A. CERAMIC INDUSTRY.—P. C. Kingsbury, (*Brit. Claywr.*, **32**, 305, 1924). From a paper in the *Journal of Industrial Chemistry*. An account is given of the American institutions at which research work is carried out, and at which educational courses in ceramics are offered.

THE ART OF THE CHINESE POTTER.—(*Pot. Glass Rec.*, **6**, 6, 1924). A review of the book of the same title by R. L. Hobson and A. L. Hetherington.

SOME MARKS ON THE DEFINITION AND MEANING OF THE WORD "CERAMIC".—J. Lœbritz (*Cer.*, **27**, 31, 1924). A reply to the Report presented by the Research Council to the American Ceramic Society. According to Oldfather, the Greek word, from which the term "ceramic" is derived, is of Sanscrit origin, and is applicable to all products obtained by the action of fire. While not disputing this hypothesis, L. is unable to accept the conclusion since the word "ceramic" was adopted by the French in the sense given to it in the Greek. If the word were used to cover all the work to which the American Ceramic Society is devoted, it would be necessary to find another word to characterise the industries at present included under the term "ceramic." The article closes with a few observations on the Report presented to the Congrés de Chimie Industrielle by Boudouard.

CHINESE PORCELAIN.—G. E. Pazausek (*Ker. Rund.*, **32**, 87, 1924). Mainly a review of the book: "Chinese Porcelain and other Ceramic Products of China," by E. Zimmermann (Leipzig, 1923, 2 Vols.) As Curator of the Dresden Porcelain Collection, Z. occupies a position which fits him admirably for the task. His book is not merely a masterly summary of the work of previous writers, such as Jacquemart, Le Blanc, Franks, Bushell, Hobson, etc. The author has made full use of the whole of the literature on the subject up to the French Jesuit, Father d'Entrecolles, and also of the important original markings by Hiang-Yuan Pien, etc., of the xvi. century.

REORGANISATION OF THE BERLIN STATE PORCELAIN WORKS.—(*Ker. Rund.*, **32**, 89, 1924). A discussion having arisen in the daily press to reconstitute the State Works and free them from unnecessary bureaucratic control, it is pointed out that the purpose of the works is to conduct research and develop new processes, etc., rather than to compete with private enterprise.

A THEORY OF SILICOSIS.—(Quarry, **29**, 32, 1924). A short account is given of Dr. J. S. Haldane's studies. Only certain kinds of dust are mainly responsible for producing lung disease. H. maintains that there is some process by means of which certain dusts can in time be eliminated from the alveoli of the lungs, while other kinds cannot be thus got rid of. Experiments on guinea pigs showed that, while china-clay dust inhaled in large quantities remained in the lungs the same quantity administered gradually may be eliminated almost entirely; *i.e.*, the process of elimination appears to be an acquired faculty. But the rate of elimination of some dusts, *e.g.*, quartz, is so slow, that it can never catch up the rate of inhalation. The mechanical theory of silicosis is rejected, for the reasons that (*a*) other kinds of mineral dust, equally as hard and angular as quartz, are not equally dangerous; (*b*) quartz dust, when inhaled with certain other kinds of dust, may not be dangerous. The quartzite of the Rand gold mines gives a very dangerous dust, yet the quartz of the Mysore gold field, being mixed with amorphous matter, is relatively harmless. Similarly, ganister dust, which is notoriously dangerous, seems to be harmless when mixed with fireclay dust.

Mechanical irritation may, however, be important in connection with bronchitis. Contrary to the theory of Gye and Kettle, there is no evidence that quartz dust is dissolved in the lungs, producing toxic effects, but there is every reason to believe that it may remain there for indefinite periods. Furthermore, the solubility theory does not explain why certain other dusts, containing up to 35% silica, are not dangerous. H. takes the view that dusts are harmful in proportion as they are physiologically inert, since they tend to remain in the lungs, while those that excite physiological reactions are ultimately eliminated. It therefore follows that a dust which is harmful by itself may be innocuous when mixed with other ingredients capable of inducing expulsion. It is recognised, however, that the problem has not been definitely solved; further observation and experiment is necessary. Furthermore, any gritty dust in the lungs acts as our irritant, and may produce increased liability to bronchitis, even though it may not cause a condition favourable to fibrosis and phthisis.

Abstracts.

I.—RAW MATERIALS.

General.

SILICA.—R. B. Ladoo (*Brit. Claywr.*, **32,** 310, 1924). The forms of silica used industrially, its occurrence and production, mining and milling methods, specifications and tests, and general utilization in industry are briefly discussed.

ELECTRIC DREDGES FOR MINING FLORIDA KAOLIN.—L. E. Riddle, Jr. (*Cer. Ind.*, **2,** 296, 1924). The Florida kaolin is classed as a secondary deposit and is in horizontal, not pocket, formation. The clay is mined 15 or 20 ft. under water, necessitating dredging. The dredge is electrically operated from a central power station. (2 illustrations).

BAUXITE PRODUCTION STATISTICS.—(*Cer. Ind.*, **2,** 297, 1924). Statistics published by the U.S. Department of the Interior for 1923. The figures are : 522, 690 long tons, worth 3,156,610 dollars, an increase of over 72% over 1922 production.

RAW MATERIALS: OCCURRENCE, PREPARATION, ETC.

CLAY RESOURCES OF SOUTHERN SASKATCHEWAN.—(*Bull. Imp. Inst.*, **21,** 505, 1923). A summary is given of a paper from the office of the High Commissioner for Canada. The work was carried out by W. G. Worcester, the tests being performed in the Ceramic Laboratory of the University of Saskatchewan. Details are supplied of the clay deposits in the Eastend—Ravenscrag, and in the Readlyn–Willows districts. The results obtained from the investigation warrant the conclusion that, considering the abundance of suitable clays in Saskatchewan, a plant might with advantage be established in the Province for the manufacture of pottery, earthenware, or floor and wall tiles. At present, the clay-working industry is confined to brick and tile making.

THE PURIFICATION OF BAUXITE.—W. A. C. Newman (*Chem. Age., Metallurgical Sect.*, **10,** 42, 1924). The processes dealt with include the Bayer process, the Peniakoff process, the Serpek and the Deville-Pechiney, or Dry Soda, process.

GRINDING CLAYS.—D. Brown (*Brick*, **64,** 734, 1924). No radical change in methods for grinding clays for brick making has taken place within the last 30 years, though machines have been improved in constructional detail. Lumpy clays should first be passed through a granulator before grinding. For clays containing many stones, a conical or beaded roll crusher should be used. For best results, the material should be fed continuously at an even rate by means of a feeder or granulator. Dry pans are employed for clays having less than about 10% moisture. From 60 to 75% of the power required to drive a dry pan is used up between the screen plates and the scraper, and not in the actual grinding. Other less common types of mills are briefly discussed.

Patents.

ALUMINA.—A. Hurter (*Pat. J.*, 1,816, 1923). No. 203,798, June 15, 1922. Alumina, in a form soluble in acids, is obtained by heating crude aluminium sulphate with solid, liquid or gaseous reducing agents to a dark red heat. When H_2S is employed as reducing agent, sulphur is liberated in considerable quantities. The iron may be removed by dilute acids. Various methods of carrying out the process are outlined.

TREATING CHINA CLAY.—T. M. Stocker (*Pat. J.*, 1,846, 1924). No. 214,962, Mar. 17, 1923. China clay is made into a suspension with 80-200% of water together with a small percentage of alkali silicate. The suspension

is allowed to stand until at least 50% of the clay has settled, when the fine clay remaining in suspension is collected by means of a filter-press and may be washed and dried. The liquid to be filter-pressed should be of not less than 1·07 sp. gr., preferably 1·12–1·135, and the discarded portion of the clay may amount to about 80%.

PHYSICAL AND CHEMICAL PROPERTIES, TESTING, ETC.

KAOLINS, CLAYS, ETC.; COLLOIDAL PLASTICITY.—A. Bigot (*Cer.*, **27**, 85, 1924). A continuation of the author's study of colloidal plasticity of kaolins, clays, infusorial earths, bauxite, ochre and slate. These materials were wet-ground to an impalpable powder and passed through a silk sieve. Suspensions in water were treated with a few drops of various reagents. The results, which are tabulated, are "inexplicable at present."

ON THE CHEMICAL CONSTITUTION OF SILICATES.—B. Gossner *Cent. Min.*, 129, 1924). Continuation of previous papers, the object being to include analyses of the various chlorites in the author's scheme. The composition of the too commonest chlorite types, prochlorite and klinochlor, justifies their inclusion under one simple and fundamental formula.

ON THE DENSITY OF QUARTZ, ORTHOCLASE, ALBITE AND ANORTHITE.—L. Ahlers (*Zeits. Kryst.*, **59**, 293, 1924). The object of the work was to study the varying data on the density of minerals on a broad experimental and literary basis, in order to arrive at exact values for the density of plagioclase. The subject is studied under : Definition of density ; methods employed and errors involved therein ; normal quartz ; density of (*a*) pure orthoclase ; (*b*) pure albite ; (*c*) pure anorthite. In the summarised results, the density of pure quartz is given as 2·6528 ± 0·0003 when weighed in air, and 2·6507 ± 0·0003 in vacuo.

REFRACTORY POSSIBILITIES OF SOME GEORGIA CLAYS.—R. T. Stull and G. A. Bole (*J. Amer. Cer. Soc.*, **6**, 663, 1923). Both laboratory and furnace tests were applied. The Georgia sedimentary kaolins, bauxitic clays and bauxites tested showed (*a*) deformation values from cones 34 to above cone 39 ; (*b*) superior load-carrying capacity and (*c*) good resistance to spalling. The results demonstrated that these refractory materials can be made into fire bricks in a practical way both by the dry press and the wet mould-repress processes. Furnace tests indicated that bricks made from these clays were at least equal to, and in most cases superior to, fire clay and silica fire bricks in service.

THE COLLOIDAL NATURE OF CLAY.—A. Fodor and B. Schoenfeld (*Koll.-Chem. Beihefte*, **19**, 1, 1924). The authors investigated the behaviour of electrolytes towards suspensions of clay with particular reference to the rate of sedimentation, coagulation, peptisation, cataphoresis, adsorption, and swelling. It is shown that the behaviour of different alkalis varies fundamentally. In small concentrations, ammonia increases the stability of clay suspensions, but in larger quantities causes an ultramicroscopic aggregation of the particles without effecting a microscopic coagulation. Sodium hydroxide, however, in small amounts, effects the coagulation of the coarser particles, and in large quantities causes quantitative precipitation. The critical alkali concentrations are not only dependent on the hydrogen-ion concentration, but also on the quantity of clay contained in unit volume. Alkali hydroxide is adsorbed by the clay and the adsorption curve is found to be of the normal type. Relatively small quantities of calcium hydroxide bring about considerable coagulation, and with increasing concentration the volume of the coagulate increases. This is attributed to peptisation and subsequent adsorption, which view is supported by the fact that, in general, lime acts as a dehydrating agent. Furthermore, the form of the adsorption isotherm of calcium hydroxide by clay is in keeping with this view. Clay which has adsorbed calcium hydroxide never regains its previous power of

adsorbing this substance, even after thorough washing.

The precipitation of clays by alkalis differs considerably from that produced by acids, this difference being seen in the relatively greater density of the coagula produced on the addition of acids. Small amounts of acid increase the stability of the suspension, but large amounts bring about immediate coagulation. Salts in small quantities increase the stability of suspensions, while in larger quantities coagulation is accelerated. Humus acids and phosphates exercise a protective action on clay suspensions. The peptising action of phosphate is independent of the hydrogen-ion concentration and in keeping with its adsorption of clay ; phosphates tend to stabilise the suspensions. The results communicated were all obtained from experiments of a qualitative nature. (Abstract in *Abstracts of Chem. Papers*, March, 1924).

II.—MANUFACTURING PROCESSES:

GENERAL.

THE MAKING OF EARTHENWARE UP TO, AND INCLUDING THE BISCUIT FIRING.—E. Shenton (*Pot. Gaz.*, **48**, 1789, 1923). Report of a lecture, delivered at the Royal Society of Arts, the object being to give a general account of the manufacture of earthenware for the benefit mainly of salesmen.

THE PRODUCTION OF EARTHENWARE FROM THE BISCUIT STATE.—E. Shenton (*Pot. Gaz.*, **48**, 1947, 1923). Continuation of above. A very lucid account of the decorating processes is given.

ELECTRICAL STONEWARE.—(*Brit. Claywr.*, **32**, 292, 1924). The method of manufacture is briefly outlined. Variations in size and shape must be avoided, so that absolute uniformity of composition is essential. Each material should be dried, ground and screened separately before it is weighed, if the maximum accuracy is to be obtained. The practice of adding the residue of one batch to the next is very objectionable. It is much better to collect all the residue until sufficient is accumulated to produce a batch, and then to grind this more finely and adjust its composition if necessary.

CHEMICAL STONEWARE.—G. H. S. Tupholme (*Manchester Guardian*, 18, March, 1924). The article deals in general terms with : the raw materials, preparation, properties, etc. ; making, moulding, etc. ; drying ; firing ; chemical and physical properties of finished ware ; different qualities of stoneware. The raw clay should be practically pure aluminium silicate with only slight traces of iron, magnesia or lime. It must be mechanically strong, and have a wide variation between vitrification and fusion point. The raw clays are pulverised, cleaned, screened and pressed ; they are then mixed with other suitable ingredients, pugged, and formed into blocks. They are then stored in concrete bins and allowed to "age" for a period averaging about 2 years. The manufacture of chem. stoneware is mostly done by hand in plaster moulds, etc. Some forms (pipes, cylinders, etc.) are extruded, while others are cast. Drying is probably the most difficult operation. This is done in heated rooms, tunnel dryers, or in the open, the process being conducted very slowly. The ware is fired in circular kilns to a temperature of 1,200–1,300°C., and is usually salt glazed. The entire kiln operation generally occupies about 20 days. The pieces are finally tested and polished with carborundum. Stoneware will resist any acid except hydrofluoric. Caustic alkalies also have little or no action. Tensile strength varies between 1,000 and 2,000 pounds per sq. in. ; compressive strength 25,000 lb. per sq. in. ; thermal conductivity 0·5 to 6 B.Th.U. ; specific heat 0·2 ; specific gravity 2·15. Tensile strength varies according to the nature of the ware. An 18-in. stoneware exhaust fan impeller has been run at 4,500 r.p.m. without bursting. Almost any shape can be made in stoneware, *e.g.*, acid tower sections, 24″ to 36″ diameter ; hollow balls, 2″ to 4″ diam. ; nitric acid receivers ; exhausters with a capacity

of 2,500 cu. ft. per min. ; cooling systems ; pipes and fittings, etc., etc. Stoneware may be divided into 7 classes : (1) porous, light and open body, through which liquids can pass, but which will hold hot acid gases. Used for filtering media, and where sudden changes and high temp. are encountered ; (2) semi-porous, open and rough, of coarse grain, suitable for furnace blocks, heavy piping, etc. ; (3) fine structure and close grain, smooth and bright finish ; for boiling kettles, hot towers, etc., where uneven heat action is met ; (4) tough and rugged, not so fine as (3), and denser than (2) ; for large acid vessels, heavy tanks, etc. ;(5) close and dense, in any size and thickness ; the most popular type ; used for receivers, tanks, jars, pans, etc. ; (6) very fine and close texture, but will not stand heat so well; cover pitchers, pumps, sinks, filters, etc. ; (7) still finer ; faucets, cocks and small vessels.

MODERN METHODS OF MAKING SILICA BRICKS.—C. H. Heubling (*Tonind. Ztg.*, **48**, 34, 1924). The modern tendency is to develop the preparatory crushing of the quartzite with the object of reducing the work of the edge runner pans to a minimum. This tendency is the result of an attempt to secure increased efficiency for a small output. Though considerable improvement has undoubtedly been effected of recent years in the edge mill, yet no striking success, from the point of view of increased efficiency accompanied by low installation costs, economy of power and reduction of the wages bill, has yet been attained. The idea of increasing efficiency by a systematic change in the methods of preparation formed the basis of a new manufacturing process introduced at the iron works of Esch and Stein, of Duisburg. As is well known, it is of great importance to the durability of a silica brick that the ground quartzite should be, as far as possible, of uniform grain-size. The problem was, therefore, to develop a method of preparation, which would not entail high installation costs, which would ensure economy of power, time and space, and which would satisfy the most severe requirements as regards the grain-size of the ground material.

Experience gained in various brick works justified the conclusion that, by transferring the main work of preparation to the initial grinding plant, the work of the edge mills would be shortened considerably. At the same time, however, the important question arose as to whether, and with what effect on the finished product, the work of the edge runners could be curtailed or even eliminated. It was found in the preliminary experiments that, after having passed through a specially constructed roller crusher, the quartzite showed promise of giving every satisfaction as regards grading. The edge mill then served the purpose simply of further reducing the size of the quartzite to a slight extent, and also of effecting a thorough mixing of the lime with the quartzite, an operation which occupied comparatively little time. Both the raw body and the fired bricks made in this manner proved equal in quality to those prepared mainly by the edge mill process. The success achieved in these first attempts encouraged the above-mentioned Firm to proceed with and develop the process, and it was subsequently found that, by introducing a second roller crusher, the grinding of the quartzite could, in a single operation, be carried to the same extent, as regards the grading of the particles, as material ground in the edge mill. But since a further grinding would have had a detrimental effect on the grading of the material, the edge mill, in which the mixing of the lime was carried out, was fitted with runners of a much lighter type. In these tests also the final product proved to be of an equally good quality.

COMPOUNDING AND PREPARATION OF BODIES, ETC.

MANUFACTURE OF CALCAREOUS FAYENCE FROM TERAYAMA WHITE CLAY AND IWAKI SHALE.—Jirokichi Kumazawa and Takehiko Ukisu. (*Tokio Industrial Lab. Bulletin* XVIII No. 3, 1923). Terayama white clay is a fine siliceous clay found at Terayama, Izumimura and Enyagun in the Tochigi Prefecture. It is a decomposition product of liparite. Its analysis gives: Loss on ignition 3·66, silica 79·25, alumina 14·16, ferric

oxide 0·59, lime 0·19, magnesia 0·08, potash 0·04 and soda 0·36%. It burns white and melts at Cone 28-30. On the other hand, Iwaki shale, chiefly produced in the Akai district of Iwakigun, is a fireclay with a refractoriness of Cone 31–34. Wares made of 30 different compounds consisting of 15–35 Iwaki shale, 5–30 limestone and 80–35 Terayama white clay were biscuited at Cones 3a, 5a and 6a and then glost-fired at Cone 05a after applying the glaze: $\left.\begin{array}{l}0{\cdot}55PbO\\0{\cdot}10K_2O\\0{\cdot}25Na_2O\\0{\cdot}10CaO\end{array}\right\}0{\cdot}30Al_2O_3:\left\{\begin{array}{l}3{\cdot}0SiO_2\\0{\cdot}5B_2O_3\end{array}\right.$ The results in short are:

(1) The white clay favours shivering, no compound being safe for three biscuit temps., though a few were free from shivering at each temp.; (2) Iwaki shale cannot be used for pure-white ware. The authors experimented at the same time, on 24 different mixtures, consisting of 20–35 Tokiguchi Gairome (plastic kaolin), 5–30 limestone and 75–35 Terayama white clay in a similar way, with the result that those with the proportions 25 : 15 : 60, 30 : 10 : 60, 30 ; 15 : 55, 30 : 20 : 50 and 35 : 15 : 50 give excellent results for any of the three biscuit temps. S. KONDO.

PATENTS.

MAGNESIA REFRACTORY.—K. Harr (*Pat. J.*, 1826, 1924). No. 207172. Nov. 7, 1923. Natural magnesite, poor in iron, or artificially prepared magnesia, *e.g.*, the final solution in the manufacture of potassium, is mixed with the residues produced during the manufacture of aniline containing iron, and the mixture dried, moulded and baked. According to an example, magnesia slime is mixed with so much "iron oxide" from aniline oil residues that the finished brick contains 84–89 per cent. MgO, 4–8 per cent. Fe_2O_3, 0·1–2·5 per cent. Al_2O_3, 1–2·5 per cent. CaO and 2–6 per cent SiO_2.

REFRACTORY MIXTURE.—Buffalo Refractory Corporation (*Pat. J.*, 1,827, 1924). No. 207,677, Oct. 24, 1922. The mixture consists of 10-55% of graphite, 20-80% of a refractory electric furnace product, such as silicon carbide, fused magnesite, fused alumina, or fused silica, up to 25% of flux, such as felspar, and a carbonising binder, *e.g.*, molasses, pitch or tar. The mixture is moulded, and heated to carbonise the binder. It is then dipped into a liquid flux, such as sodium borate, or silicate, and heated to 1,200°F.

REFRACTORY SUBSTANCE.—J. J. Loke (*Pat. J.*, 1,836, 1924). No. 210,708, May 14, 1923. The slag which is obtained in manufacturing iron from oxidised titanic iron, and which consists chiefly of titanium oxides, is mixed with a small proportion of a binding agent and used for lining furnaces or making refractory articles.

BASALT PRODUCTS.—Compagnie générale du Basalte (*Pat. J.*, 1,840, 1924). No. 211,846, Jan. 17, 1924. Basalt is mixed with a fusible or refractory substance, *e.g.*, clay or clayey sand, and either fused and moulded, or moulded and subsequently baked.

MAGNESITE REFRACTORY.—Dynamidon-Werk Engelhorn & Co., R. Engelhorn and J. Schaefer (*Pat. J.*, 1,840, 1924). No. 211,873, Feb. 20, 1924. A refractory material is prepared as follows:—Raw or calcined magnesite or magnesia is fused, cooled, and crushed, and is made into bricks, or applied as a coating and burnt at a high temperature in the usual manner. A portion of the fused material, which has been finely ground, serves as a binding agent, and sintered magnesite may also be added. Temporary binders, such as tar and dextrin may be employed. The material should be as free as possible from lime and iron. The latter impurity may be removed by fusing under reducing conditions and passing the fused material through a magnetic separator.

REFRACTORIES CONTAINING MAGNESITE, DOLOMITE, ETC.—J. Hodson (*Pat. J.*, 1,840, 1924). No. 211,944, Nov. 28, 1922. Refractory bricks, furnace linings, etc., are made from raw, or a mixture of raw and calcined rocks containing magnesium and calcium carbonates, such as dolo-

mite or magnesite, together with (1) talc, steatite, or other magnesium silicate, or (2) igneous rocks with or without basic iron cores, or (3) silica sand with either magnesium silicate, or igneous rock or clay, the mixture being moulded with or without a glutinous binder and burnt, or burnt to a plastic state and then moulded. Typical examples are as follows:—15% silica is mixed with 5% terpentine, 10% raw dolomite, and 70% burnt dolomite, or 92·5% raw magnesite is mixed with 5% silica sand and 2·5% clay.

SHAPING, MOULDING, DRYING, ETC.

THEORY AND PRACTICE OF HUMIDITY DRYING.—(*Corr. Cer.*, **5**, 68, 1924). Evaporation of moisture from the surface of an object has a perceptable cooling effect, which lowers the vapour pressure of the surface moisture. But, since vapour pressure always tends towards equilibrium, there is created, at the moment when a difference in pressure exists, a condition in which moisture from the interior is attacted towards the surface. As the vapour pressure of the surrounding atmosphere is allowed to fall gradually, this movement of moisture from the interior continues, until the vapour pressure throughout the whole mass corresponds with that of the surrounding air. A description is given of the American "Humidity Dryer."

PATENTS.

ELECTRIC INSULATORS.—R. J. P. Briggs, H. S. Newman and Bullers (*Pat. J.*, 1,845, 1924). No. 213,655, Dec. 30, 1922. A tabular insulator is described, which is unitary in structure, substantially vacant as to the whole of its length, sealed fluid-tight at its ends, and constructed so that the path of possible discharge outside the tubular body is electrically shorter than the path inside.

TEA AND COFFEE POTS; SPOUTS.—E. W. Abrams (*Pat. J.*, 1,846, 1924). No. 214,073, Mar. 29, 1923. A channel is disposed below the spout and is adapted to catch the drips therefrom and to return the liquid to the vessel through the lid opening. The ridge forming the channel also serves to protect the lip of the spout.

TEAPOT LIDS AND COVERS.—J. Webster and Lingard, Webster & Co. (*Pat. J.*, 1,838, 1924). No. 211,369, Apr. 12, 1923. The lid of a teapot, coffeepot, etc., has a rearward extension provided with a depending part, adapted to fit into a hole formed through the top of the handle.

DRYING KILNS.—S. Vivian (*Pat. J.*, 1,843, 1924). No. 212,986, Dec. 19, 1922. The sole, or hearth, beneath which hot gases are passed, and on which the material (*e.g.*, wet china clay) is spread, varies in composition along its whole length in such a manner that the transference of heat through it is substantially uniform throughout. The heat-insulating layer may be of diminishing thickness from the furnace to the chimney end, or it may be of uniform thickness and varying conductivity.

ROOFING TILES.—J. Lovell (*Pat. J.*, 1,843, 1924). No. 213,200, Oct. 10, 1923. The tile shown is so shaped as to comprise a number of flat parts in different parallel planes, with angular connecting portions.

KILNS, OVENS, MUFFLES; FIRING TECHNIQUE, ETC.

THE NECESSITY OF EFFICIENT COMBUSTION CONTROL.—D. Brownlie (*Glass*, **1**, 77, 1924). The Combustion Recorder, an instrument which automatically takes 20 samples of exit gases per hour and determines and records the percentage of CO_2 by analysis, is of priceless value in controlling combustion. In the most modern machines the percentage of CO and unburnt gases is also determined at the same time. The advantages of firing with pulverised coal are pointed out.

GLASS WOOL HEAT INSULATION IN EUROPE.—A. D. Saborsky (*J. Amer. Cer. Soc.*, **6**, 676, 1923). The experiences of several European

concerns using glass wool for insulating purposes are recounted. The thermal conductivity of glass wool is lower than that of any other insulating material at present employed. It has many other properties which render it highly suitable as an insulator. The methods of manufacture are described.

AUTOMATIC STOKING OF HOFFMANN KILNS.—(*Rev. Mat. Constr. Trav. Pub.*, No. 173, 29B, 1924). A short abstract of a paper by Dumortier from *Monde Industriel*. The advantages of automatic stoking are pointed out.

COMPARISON OF STEEL REFRACTORIES.—(*Foundry*, **52,** No. 5, 1924). At a recent meeting of the American Ceramic Society, several speakers stated that cone tests do not afford accurate criteria of temperature-withstanding abilities of refractories. Cones made by firms in different countries were shown to give results differing sometimes by two numbers, and bricks fusing at cone 27 or 28 had given much better service in the chequers of open-hearth regenerators than 31-or 32-cone bricks.

A representative of the Bethlehem Steel Company gave interesting data as to the practice of his firm in lengthening the life of furnace roofs. When parts of a brick fell out and left a hole, it was more often due to faulty construction than to inferior bricks. Their practice was to take all the bricks from one lot in order to ensure uniform quality, and then to gauge them for size. The bricks were put in place in the roof without anything between them, great care being taken in keying, to ensure that both outer and inner edges should be in contact across the entire arch. When the furnace was fired, the operators allowed for expansion by slackening the tie-rods. This avoidance of shearing pressure was stated to be most vital, as a brick glazes only on its original skin. The inner surface which is exposed to the flame after part of the brick has fallen away, will not glaze ; hence the less refractory interior of the brick fuses in the high temperature and causes a weak spot in the roof. As a result of this practice the company has overcome 90 to 95 per cent. of its roof failures.

EFFECT OF OPERATIONS ON FURNACE LINING.—C. A. Smith (*Foundry*, **52,** No. 5, 1924). The reasons for the much greater life of the acid as compared with the basic furnace are first pointed out. The silica roof, the ports and the chequers are the general determining factors in the life, the first two being the most troublesome. The usual American port design leads to failure of the nozzle, and in consequence, water-cooled steel ports have been introduced. It is a common practice to introduce an oil burner through a gas port while ports of the gas producers of a producer gas furnace are being repaired, but the life is often reduced about 50 per cent. thereby, since the roof is much too low to withstand the intense heat generated by the oil flame. By raising the roof several feet, oil-firing gives a fast working furnace, which has a much shorter life than the gas-fired type, but the increased production outweighs the cost of rebuilding. Of the different grades of charges, high-carbon steel is least severe on the open-hearth furnace, the slag being less oxidising and the time taken less than in the low-carbon process.

The most desirable refractory is that which will cost least per ton of steel produced. If, by frequent renewal of linings at a fairly low price, a fast working furnace will give a production large enough to offset the cost of such new linings, the operation may be considered satisfactory.

KILNS FOR SMALL BRICKWORKS.—(*Rev. Mat. Const. Trav. Pub.*, No. 173, 23B, 1924). From a paper by A. Schmidt in *Baumarkt*. A small brickworks, producing one to one-and-a-half million first-quality bricks, has the choice, for burning purposes, of a chamber kiln, an annular kiln, or a zig-zag kiln, the selection depending upon the working expenses for a given annual production. A chamber kiln can be burned off completely (including charging and discharging) in about 12 days *i.e.*, about 5 burns every two months. For an annual production of 1½ mill., 125,000 bricks must be fired per month, or 50,000 per kiln. For practical reasons, it is better to have two small

chambers rather than one large chamber. To produce the same quantity of bricks, an annular kiln of at least 16 chambers 1·8 metres wide would be required. With a kiln of this type, having a firing chamber 74 m. long, from 6,500 to 8,000 bricks, can be fired daily, so that the lower figure 1½ mill. bricks could be burned in about 8 months. The corresponding zig-zag kiln would have 12 chambers of the same width as the annular kiln. A great advantage of this type is its long firing space, due to the disposition of the chambers. The doors to the zig-zag kiln are in the front wall of the chambers, so that the trucks can be admitted and withdrawn in a straight line. The width of the tunnel can thus be reduced somewhat, and for this reason, the kiln is very suitable for tiles. The costs of construction for a 12-chamber zig-zag kiln are about 20% higher than for a periodic kiln with two chambers side by side, whilst a Hoffmann kiln would cost about 40% more than the latter.

ON THE WASTE GASES OF TANK FURNACES.—Hideo Iwai. (*The Asahi Glass Co. Bulletin* No. 9, 1923). Elaborate expts. on the waste gases of the Siemen's regenerative tank furnace at the Tsurumi plant of the Co., manufacturers of window glass, are described. The reversal of air and producer-gas currents occurred every 20 min. Results: I. Temp. of the waste gases. The average temperatures at the outlets of the air regenerators, the inlet of the air valve, its outlet, the middle of flue and the foot of stack were 466°, 432°, 330°, 316° and 301°C. respectively. II. Composition of the waste gases, Analysis of the hot gases, expressed in volume per cent. at the inlet and outlet of the air-reversing valve gave:

	CO_2	O_2	N_2	H_2O
At the inlet	9·9	3·0	71·9	15·1
At the outlet	7·9	6·2	74·0	12·0

III. Amount of waste gases, leakage of air at the value, and calculation of air-excess. The amount of gases at the in- and outlets of the valve were 12·73 and 15·97 l· per kg. of coal respectively. The leakage of air at the air valve was 25·4% in volume. Excess of air was 39·6%. IV. Calculation of the waste heat. The heat of the waste gases at the inlet of the air valve corresponded to 39·5% of that generated by coal, taking the latent heat of water vapor in consideration. S. KONDO.

NEW FORMS OF KILNS.—C. Roschmann (*Ker. Rund.*, **31**, 444, 1923) Criticism of a paper by Sir A. Duckham, entitled: "Some New Forms of Kilns". Roschmann writes: "A tunnel kiln is described in which cross walls are provided on each truck, these cross walls registering with offsets on the kiln walls, so that a number of chambers are formed. This arrangement is said to force the gases to take a zig-zag path, thus rendering possible a reduction in the length of the kiln from 300 to 130 ft. To the practical man, who has had years of experience in the working of tunnel kiln, this invention will appear of little value. The assumption that the tunnel can be shortened is false. All ceramic wares require definite pre-heating and firing periods, which cannot be reduced with impunity. This method of conducting the gases through the kiln merely implies that these firing periods are slowed down, thus reducing the efficiency of the kiln, which, it must be remembered, is intended to be a high-efficiency apparatus. Furthermore, the cross walls tend to interfere with the cooling of the ware, which therefore leave the kiln too hot. If the gases are passed through flues built in the kiln walls, considerable loss of heat by conduction and radiation will result. The partition walls occupy space which in a tunnel oven is particularly valuable. They are also difficult to construct and are of low stability, especially at high temperatures. Constant repairs will be necessary. The offsets on the kiln walls are particularly dangerous. In order to effect a satisfactory "seal," so as to force the gases in the direction required, the space between cross wall and offset must not be more than three-quarters of an inch (20 mm.) But, as a result of the expansion due to heat, this space will disappear, the cross walls

will jam with the offsets and a stoppage is inevitable. A second innovation concerns a circular tunnel kiln. The opinion is widely held that the circular tunnel is more easily heated that the straight. Satisfactory proof of this, however, is not forthcoming. There is no reason, therefore, why this complicated construction should be chosen in preference to the straight type, with the intention of saving trucks. As a rule, the foundation of a circular kiln has to be constructed of iron, on which the refractories are placed. The heat in the hot zone causes this foundation to lose its circular form, and stoppages are the result.

THE SUITABILITY OF THE TUNNEL KILN FOR BURNING REFRACTORIES.—A. F. Greaves-Walker and S. M. Kier (*Claywr.*, **80**, 248, 1923). In the Report of the Committee on Fuel Conservation in Tunnel Kilns, presented at a meeting of the (American) Refractories Managers' Association, details are given of a tunnel kiln which is firing refractories at the plant of the Ohio Valley Clay Co., Steubenville, Ohio. This kiln is 303 ft. long and the cross-section measures approximately 4 by 6 ft. It will hold 47 cars, each 6 ft. long. Natural gas is used as fuel, and cone 2 is bent in the centre of the trucks. The entering air has a temperature of 200°F and the exit air 250°F. The maximum charging rate is two hours. The hot zone is 75 ft. in length, and the lining throughout is of Mt. Savage firebrick. The kiln was built in 1917-18, and during the first five years of operation repair costs have been very low. The approximate cost, at a period when prices were high, was 120,000 dollars. The refractory car tops last approximately one year.

The kiln is used exclusively for burning fireclay shapes, many of which are large and would be classed as difficult. This accounts for the 94-hour firing period. It is practically impossible to estimate the capacity of this kiln in 9-inch equivalent, or to compare its output with that of the average fire brick plant. It may safely be said, however, that no more difficult ware is made on any plant in the world, and since the losses are practically nil, it may be assumed that any similar type of product could be handled safely under the same conditions.

An investigation of the European situation revealed the fact that, in Germany and France, the tunnel kiln is considered perfectly successful for burning fireclay refractories of any type. At the present time, there are two kilns operating on silica bricks entirely and two under construction. The two former are at the plant of Dr. Otto and Company at Bendorf, Rhein, and are known as Otto kilns. The first of these was started in 1913 and was originally 100 metres long. This was found to be too short and the kiln was extended from time to time, mainly on the cooling end, until in 1919 it had reached the length of 160 metres, or 528 ft. A second kiln of this length was constructed in 1921, indicating that the first was successful. These kilns are burning silica bricks and shapes used almost exclusively in coke-oven construction. The raw material employed is Westerwald quartzite and the ware is fired to cone 14. It is interesting to note that these kilns are fired with producer gas without preheating. *Conclusions.*—As a result of its investigations, the Committee feels safe in concluding that the tunnel kiln has been developed to a point where it will burn fireclay refractories of any type equally as well as the down-draught kiln. It would, of course be necessary to design a kiln especially for each operation after careful tests of the raw material and mixtures and the establishment of a firing curve. It is maintained that the open type will burn any fireclay refractories successfully that can be fired in the muffle type, and *vice versa*. Selection would therefore be governed by the question of first cost.

The question of capacity is important. No kiln, as far as the Committee is aware, has yet been built which produces more than 18,000 nine-inch equivalents per 24 hours. This, however, is not considered the limit at the present stage of development. It is believed that kilns could be built which would successfully deal with 30,000 or 32,000 per 24 hours fired to cones 12 to

14. It is very largely a question of total length of kiln, length of hot zone, type of fuel used, and method of burning fuel. In order to produce 32,000 nine-inch bricks per 24 hours burned to cone 12, the following general specifications would apply:

Length of kiln 360 ft. ..	Burning period 72 hours.
Length of truck 7′ 6″. ..	Charging rate $72 \div 48 = 1\frac{1}{2}$ hours.
No. of trucks 48 ..	No. of trucks $24 \div 1 \cdot 5 = 16$ per day. No. of bricks per day $= 2{,}000$ per truck $\times 16 = 32{,}000$.

Although these figures are only theoretical, several kiln engineers have agreed that the kiln with a 30,000 capacity is now possible. In firing silica refractories in tunnel kilns, the problem is one of cooling rather than of heating up. If a large output is required, temperatures of cone 18–20 present a somewhat difficult problem. The successful burning of silica materials is not only a question of bond, but also one of inversion, which introduces a time factor. Exposure to a certain temperature for a certain length of time is necessary in order to produce a commercial silica brick, and the only way in which this period can be shortened is to use higher temperatures. To produce the necessary volume of heat to burn any considerable number of silica bricks would require either a long burning zone or regenerators, which imply high construction costs. Furthermore, the inversion points during the cooling period must be taken into consideration in designing the kiln.

To meet the requirements of the average silica brick plant in America, a daily output of at least 24,000 nine-inch equivalents would be necessary. This is a relatively small unit, but it is questionable whether a tunnel kiln of standard design could be built and operated economically for a larger capacity. The theoretical specification for a 24,000 capacity kiln would be—

Length 540 ft. .. .. Burning time 6 days = 144 hours.

Cross section 5 ft. by 6 ft. Charging rate effective $= \frac{144}{72} = 2$ hours.

Trucks $7\frac{1}{2}$ ft. long. .. No. of trucks $= \frac{24}{2} = 12$ per day.

No. of trucks $= \frac{540}{7 \cdot 5} = 72$. 2,000 bricks per truck $\times 12 = 24{,}000$ per day

A larger output might be obtained by building a longer kiln and charging the cars at one-hour periods, but the truck capacity would then have to be reduced to 1,500 bricks or less. Such a kiln would have to be 715 ft. long and would produce from 30,000 to 35,000 nine-inch per day. The burning curve would be as follows:

Advance.	Drop.
40 hours at 20° per hour.	7 hours at 20° per hour.
19 ,, ,, 65° ,, ,,	13 ,, ,, 123° ,, ,,
18 ,, ,, 20° ,, ,,	15 ,, ,, 40° ,, ,,
	4 ,, ,, 20° ,, ,,
77 hours.	39 hours.
	Total 116 hours.

A much shorter kiln, however, could be used, and the capacity probably increased by the application of the regenerative principle. According to the designs for such a kiln which were submitted to, and favourably considered by the Committee, two lines of cars move in opposite directions, and the use of regenerators makes it possible to build up temperatures in a manner impossible in the standard type.

The question of the best fuel to use for a tunnel kiln also

received attention. In Europe producer gas is employed almost exclusively, and has been shown to be highly successful in Amercia also. Its disadvantage lies in the fact that, owing to the deposition of tar and soot in the flues, it is necessary to "burn out" periodically. This drawback has been overcome to some extent by a new system, developed by the Cottrell Company, in which these troublesome ingredients are precipitated electri cally, so that the gases are perfectly clean as they pass through the flues. With regard to the fuel-saving advantages of tunnel kilns, it is pointed out that in other industries it has been found profitable to replace the old systems with the tunnel type. In one instance it was reported that, on a tunnel kiln which had been in operation for six months, and which cost 50,000 dollars to build, the saving on fuel alone for the first year would amount to 60,000 dollars. As the percentage saving in fuel would be the same in one industry as another, it is assumed that the refractories industry would average a saving of at least 75 per cent.

RECLAIMING LOST FUEL.—(*Tonind. Ztg.*, **47**, 731, 1923). It is a well-known fact that it is still impossible to effect complete combustion of the fuel in kiln grates, much combustible material being regularly thrown away with the ashes. Considerable attention has been devoted of recent years in Germany to the problem of regaining this waste fuel. One of the latest processes brought out is that known as the "Amber-Works Wet Process." The machine used in this method is known as the "Komet" and is made by the Ambi-Werke A. G. of Berlin. The separation of the heavy slag from the lighter coke is effected by the agency of water. The grate ashes are first passed through a rotary sieve, which performs a three-fold separation: the grit and ashes pass out of the machine together down a separate chute, while the medium and coarse (grain-size over 60 mm.) slag goes into the machine for further separation. This coarse material is discharged from the rotary sieve down a chute and on to a coal screen, through which water is forced upward at regular intervals by means of a sort of piston within the cistern. In this way, the light coke is washed off the screen and out through a separate discharge, leaving the heavy residue to find its way through a third outlet lower down. Much of the overflow water is collected by a bucket wheel and is returned to the cistern. In an eight-hour shift, this machine is capable of dealing with 40 cu. metres of grate ashes, out of which about 5 tons of combustible material (depending upon the type of ash) may be regained. The power consumed amounts to 4 H.P. and two men are required to run the machine.

OPEN-HEARTH REFRACTORY MATERIALS.—(*Iron and Steel of Canada*, **7**, No. 2, 1924). At the Ceramic Experiment Station of the U.S. Bureau of Mines, experimental work has been started which has as its aim the production of a high alumina refractory, using a kaolinite bauxite as the raw material. Large deposits of bauxite rich in silica have hitherto proved a very limited field of usefulness, and it is hoped that these may be used to produce a less acid refractory than silica, which will, at the same time, have a higher fusion temperature. When such material is fused, or highly sintered, it can be made into a brick which will be practically free from the high shrinkage characteristic of bauxite bricks burned at ordinary kiln temperatures. The mineralogical composition aimed at is a mixture of sillimanite and corundum, together with the eutectic formed between these two materials.

It is proposed to prepare the sinter by the Lecesne method, or by a suitable modification, one suggestion being the utilization of oxygen-enriched air for the blow toward the end of the burn. A study of the possibility of increasing the proportion of tridymite in a silica brick by using a suitable flux to aid in the normally sluggish transition from quartz to tridymite has been started, but precisely to what extent this transition is possible by holding commercial bricks within the tridymite range for varying lengths of time up to two weeks, is still under investigation.

DRESSLER TUNNEL KILN FOR BURNING BRICKS.—(*Brick*, **64**, 576, 1924). An illustrated account of the first tunnel kiln built in America

in 1890, which proved a failure, is followed by a description of a modern, direct-fired, coal-burning Dressler kiln, which is now being run successfully by the same concern, the Kreischer Brick Co., of Tottenville, N.Y.

NOTE ON FUEL ECONOMY.—P. de Groote (*Corr. Cer.*, **5**, 59, 1924). A general discussion on the sources of heat losses in kilns, etc., and their prevention.

THEORY AND PRACTICE OF DOWN-DRAUGHT FIRING.—T. da Mileto (*Corr. Cer.*, **5**, 71, 1924).

SAVING DOLLARS ON THE GAS PRODUCER.—R. A. Blunt (*Cer. Ind.*, **2**, 283, 1924). Practical directions are given for regulating air-steam nozzles and for gauging the thickness of the fire-bed. The method of treating the varying qualities of coal is outlined. A chart is shown which indicates the amount of steam per hour per nozzle when the size of nozzle and average pressure have been determined.

PATENTS.

KILN STOKER.—A. Monnier (*Pat. J.*, 1,819, 1923). No. 205,066, Sept. 25, 1923. The apparatus comprises a hopper, having at its lower end a rotary disc, from which the fuel is removed by an adjustable scraper. The lower part of the apparatus consists of a two-part casing, of which the upper portion is apertured to allow the fuel to descend on to the disc, while the lower section is in the form of an elbow, and is connected to the feed opening of the furnace.

TUNNEL KILN FOR GASEOUS OR LIQUID FUEL.—N. Lengersdorff (*Pat. J.*, 1,840, 1924). No. 211,894, Feb. 26, 1924. The kiln is adapted to be heated by oppositely disposed burners arranged at the sides of the burning zone and supplied with purified producer gas, or oil. The burners may be arranged in two tiers. The gas mains are placed in the roof of the cooling zone in ducts or channels, supplied with hot air from recuperators. The hot air and gases are withdrawn by a fan from the preliminary heating zone through ducts in the side walls. The walls of the cooling zone have radiators for heating air or water for use elsewhere ; these radiators serve to cool the walls of the kiln.

UTILIZING WASTE GASES FROM CEMENT KILNS.—M. Jorgensen and E. Ronne (*Pat. J.*, 1,841, 1924). No. 212,298, Dec. 4, 1922. In a rotary kiln, to which the raw materials are fed in a wet state, a part of either the hot gases or of the raw material is kept separate from the rest in the drying and preliminary heating zone, so that a part, or the whole, of the hot gases will leave the kiln in a better state for subsequent utilization, *e.g.*, in steam-generating plant.

ANNULAR TUNNEL KILN.—Woodall, Duckham & Jones Ltd., and A. M. Duckham (*Pat. J.*, 1,842, 1924). No. 212,585, Sept. 5, 1922. The kiln, which is of the muffle type, has a number of superposed horizontal heating-flues arranged in the walls of the tunnel. These are connected singly, or in groups of two or more, to the combustion apparatus, so that the temp. may be controlled over the height of the tunnel. The kiln comprises an open loading and unloading section, a drying-section extending to a point where drying-air is admitted to the interior of the muffle, a heating-section extending to the point of combustion, and a cooling-section. The goods are carried on a travelling platform consisting of comparatively short sections connected by expansion joints, or of two or more layers of sections arranged to break joint. The roller supports and driving-mechanism are beneath the floor, and are freely exposed to the air.

GLAZES, ENAMELS.

EXPERIMENT ON RAW LEAD GLAZE.—Takeo Oshida. (*The Tokio Industrial Lab.*, *Bulletin* XVIII No. 3, 33, 1923). I. Experimental Formula of the glaze. 61 formulae of raw lead glazes found in literature have been tried in

the experiments, using white lead as the source of lead. II. Procedure. Each batch of about 300 g. was mixed with 700 cc. of water and ground for 5 hrs. The glaze was applied on cups of felspathic fayence, which was composed of 25 washed Kibushi (plastic shale), 25 Shiraetsuchi (kaolin), 15 felspar and 35 quartzite grog, biscuited at Cone 6a and partly painted with cobalt blue, chrome green and chrome pink. The cups were then glost-fired at cones 010a, 05a, 1a and 6a. III. Results. Results are shown in a table. Picking out those glazes which matured bright at two temperatures and did not craze within 2 years, we have:—

Cone No.	Average of	Average chemical formula					
		PbO	K_2O	CaO	ZnO	Al_2O_3	SiO_2
010a and 05a	3 glazes	1·00	—	—	—	0·09	1·32
05a and 1a	3 glazes	1·00	—	—	—	0·17	1·28
,,	1 glaze	0·70	—	0·30	—	0·10	1·30
1a and 6a	3 glazes	0·90	0·03	0·07	—	0·13	1·27
,,	5 ,,	0·80	0·02	0·14	0·04	0·14	1·26
,,	18 ,,	0·70	0·06	0·19	0·05	0·19	1·49
,,	9 ,,	0·60	0·12	0·17	0·11	0·23	1·73
,,	4 ,,	0·50	0·20	0·10	0·20	0·30	2·10
,,	1 glaze	0·40	0·20	0·10	0·30	0·30	2·10

Generally speaking, raw lead glaze seriously affects the underglaze colour and has a disagreeable yellowish tint due to high content of lead. Moreover, it is liable to produce flaws and is too fluid. S. Kondo.

EXPERIMENTS ON THE MANUFACTURE OF LEADLESS OVERGLAZE COLOURS.—Jikei Ueda. (*Report of the Pottery Lab., Kioto*, No. 2, 29, 1923). I. Introduction. The paper relates to the elimination of lead by bismuth. II. Manufacture of leadless fluxes. (1) Flux composed of bismuth oxide and silica. Essential constituents of lead fluxes are PbO and SiO_2, but similar fluxes, as Bi_2O_3 (1-3) SiO_2, are too hard. (2) Flux composed of bismuth oxide, alkali and silica. Flux $\left.\begin{matrix}Na_2O\\Bi_2O_3\end{matrix}\right\}$ 5 SiO_2 is still too hard and, moreover, is useless for ferric oxide red, as its high content of alkali badly affects the colour. (3) Fluxes composed of bismuth oxide, boric acid, alkali and silica. Flux $\left.\begin{matrix}K_2O\\Bi_2O_3\end{matrix}\right\}\begin{matrix}3B_2O_3\\2SiO_2\end{matrix}$ is pretty good for blue, green and black colours, although it is too sol. in water. Flux $\begin{matrix}K_2O\\2Bi_2O_3\end{matrix}\left\{\begin{matrix}6B_2O_3\\4SiO_2\end{matrix}\right.$ is better, as it is less soluble. (4) Fluxes composed of bismuth oxide and boric acid. The author obtained the best results with these fluxes. Flux I, Bi_2O_3 $3B_2O_3$, is suitable for blue, green and yellow colours. Flux II, Bi_2O_3 $4B_2O_3$, is suitable for red and black colours which require high proportions of colorants. Both fluxes were prepared by melting batches composed of boric acid and bismuth oxide or subnitrate in a biscuit crucible of chem. porcelain which had an aperture in the bottom. III. Manufacture of leadless overglaze colours. (1) Blue colour. A good blue colour was obtained when 100·0 parts of Flux I. were mixed with 10·0 blue stain which had been prepared by heating a batch consisting of 25 cobalt oxide, 50 aluminium hydroxide and 25 aluminium sulphate at Cone 10 or higher. (2) Green colour. A green of medium intensity was produced with a colour consisting of 100·0 Flux I and 7·0 chromium oxide. (3) Yellow colour. An orange yellow colour was obtained when 10 am. uranate were mixed with 100 Flux I. A colorant obtained by igniting a batch such as 16·0 stannic oxide, 32·0 antimony oxide, 52·0 bismuth oxide and 2·0 ferric oxide at about 700°C. produced a very good yellow when it was mixed with 10 times its weight of Flux I. (4) Red colour. The best proportion of Flux II and ferric oxide is 80·0:

20·0. The black shade in the red is due to the quality of the oxide. It is best corrected by adding 10 alumina to 100 ferric oxide. An excellent result was obtained when carbonates of Fe and Al were precipitated from a mixture of acidified soln. of $FeCl_3$ and aq. soln. of $Al_2(SO_4)_3 \cdot 18H_2O$ with sodium carbonate soln. It has to be thoroughly washed, dried and ignited at about 750°C. in an oxidising atmosphere. On the other hand a mixed soln. of $Fe(NO_3)_3 \cdot 9H_2O$ and $Al(NO_3)_3 \cdot 8H_2O$ may be treated with ammonia. The latter process is much more simple. (5) Black colour. The best result was obtained with a colour consisting of 20·0 stain and 80·0 Flux II. The stain was prepared by igniting a mixture of 40·0 cobalt oxide, 20·0 ferric oxide, 20·0 manganese oxide and 20·0 chromium oxide at Cone 10. S. KONDO.

EXPERIMENTS ON THE TENRIUJI-CELADON GLAZE.—Ko Ishii. (*Report of the Pottery Lab., Kioto*, No. 2, 55, 1923). I. Introduction. Tenriuji-Celadon is a kind of Celadon having a shade of deep green or slightly yellowish green. The glaze must be transparent, bright and free from crazing. II. Basic glaze and body. It is known that iron glazes rich in potash and poor in lime favour the production of Kinuta-Celadon having indigo shades, while those rich in lime tend to produce Tenriuji-Celadon which has green shades. Therefore, 9 glazes within the range of $\left.\begin{matrix}0{\cdot}2K_2O\\0{\cdot}8CaO\end{matrix}\right\}$ $0{\cdot}3\text{-}0{\cdot}5Al_2O_3$, $3{\cdot}0\text{-}4{\cdot}0SiO_2$ have been tried, adding 3·5 ferrous silicate and 0·05 chromium oxide to 100·0 batch of each basic glaze. Ferrous silicate was prepared by heating a mixture of 1 mol. FeO and 3 mol. SiO_2 to cone 11 in a reducing flame. The body was composed of 60 Amakusa, 13 felspar, 25 Gairome and 2 ferric oxide. III. Glazing and firing. The wares were dipped in, or poured with a fairly thick glaze, dried thoroughly and then coated with a thicker glaze slip, containing Funori glue, by means of a brush. The latter treatments were repeated 2 or 3 times. The glaze must be crushed to pass through a 1/16″ mesh sieve and then ground 29 hrs. in a pot mill. After glazin, the wares were fired with wood at Cone 9–10 in a reducing flame. The bgst result was obtained with basic glaze VI, which corresponds to $\left.\begin{matrix}0{\cdot}2K_2O\\0{\cdot}8CaO\end{matrix}\right\}$ e$0{\cdot}4\ Al_2O_3$, $4{\cdot}0SiO_2$ and was composed of 21·0 limestone, 14·6 felspar, 58·0 Amakusa and 6·4 silica. The colour was a bright light green. IV. Effect of chromium oxide as auxiliary colorant. Chrome green is not affected by the nature of the flame. Therefore, chrome celadon is widely made by adding chromium oxide in its glaze or body, though it appears thin and is deficient in brightness on account of its turbidity. However, its addition in small quantities as described in II, is desirable, because it makes the celadon deep green. Experiment has proved that 0·05 chromium oxide added to 100·0 basic glaze is the best proportion. V. Effect of rutile as auxiliary colorant. The addition of 0·20–0·30 rutile to 100·0 glaze VI. and 3·5 ferrous silicate produced a good green, while 0·40–0·50 rutile gave a good yellowish green. VI. Effect of manganese carbonate as auxiliary colorant. Celadon glazes containing manganese carbonate are deeply affected by the nature of the flame. However, those composed of about 4·5 manganese carbonate, 3·5 ferrous silicate and 100·0 glaze VI gave excellent green celadon when fired in a perfectly reducing atmosphere. S. KONDO.

PATENTS.

COATING PROCESS.—H. Y. Potter, F. J. Robinson, and A. Lloyd (*Pat. J.*, 1,821, 1923). No. 205,547, July 14, 1922. Hard-fired earthenware, china, etc., of finely porous material are treated with phenolaldehyde condensation products to obtain a glaze and render the objects waterproof. Hard-fired biscuit is allowed to cool, coated with a condensation product, *e.g.*, by dipping, air-dried, and fired for 30 min. at 200°F., followed by 30 min. at 250°F. Pigments or dyes may be added to the glaze.

METAL COATING PROCESS.—A. Grönqvist (*Pat. J.*, 1,839, 1924). No.

211,530, Oct.16, 1922. The body (earthenware, glass, porcelain, etc.) is embedded in a mixture of a pulverised, alkaline earth metal, *e.g.*, magnesium, and its oxide, or a mixture of pulverised light metal (aluminium) and its oxide, or a mixture of the two metals, and submitted, in a hydrogen atmosphere, to a temp. above the m.p. of the metal, but below that of the body. The metal vapours generated reduce to metal the metallic oxides contained in the body.

COLOURS, DECORATIVE PROCESSES, ETC.

PREPARATION OF SUBSTITUTES FOR CHINESE BLUE CALLED "GOSU."—Ko Ishii. (*Report of the Pottery Lab., Kioto, No.* 2, 1, 1923). I. Introduction. At present, the Chinese cobalt ore called "Gosu," which has long been the most important underglaze colour in the Orient, is scarce and, moreover, it requires tedious treatment for refining. A few years ago, Dr. H. Ueda made a study of its substitutes and patented a process in which colouring metals are precipitated as cyanogen compds. (Jap. Pat. No. 31, 722). The paper relates to the systematic study of the patent. II. Body and glaze. A porcelain body, composed of Amakusa (semi-decomposed liparite) 65, felspar 15 and Gairome (plastic kaolin) 20 and a glaze 0·178 K_2O, 0·065 Na_2O, 0·748 CaO, 0·009 MgO, 0·483 Al_2O_3, 4·73 SiO_2 was used. III. Chem. reaction and process of preparing the artificial colour. (1) $Co_2Fe(CN)_6$, $Mn_2Fe(CN)_6$ and $Ni_2Fe(CN)_6$ were pptd. from solns. of $CoCl_2.6aq$, $MnSO_4.7aq$ and $NiSO_4.7aq$ resp. with $K_3Fe(CN)_6.3aq$. (2) $K_3Fe(CN)_6$ was used instead of $K_4Fe(CN)_6.3aq$. The ppts. were washed, dried, ground and proportioned. The mixture was then ignited to remove its plasticity. IV. Comparison of cobalt ferrocyanide and ferricyanide. A colour consisting of 51·68 Korean kaolin and 48·32 $Co_2Fe(CN)_6$ proved to be a little superior to that consisting of 46·06 Korean kaolin and 53·94 $Co_3Fe_2(CN)_{12}$. Mixture of ferrocyanides of Co and Mn or Ni. Ni produces a shade of bluish black or blackish grey. Its action is more violent than that of Mn. A good purplish indigo was developed with compds. of 44·46–50·05 Korean kaolin, 41·58–46·80 $Co_2Fe(CN)_6$ and 13·96–3·15 $Mn_2Fe(CN)_6$, when fired at Cone 11 in a reducing flame. VI. Mixts. of Co., Mn and Ni ferrocyanides Among 21 batches tried, the following gave the best results:

Batch	Korean kaolin	$Co_2Fe(CN)_6$	$Mn_2Fe(CN)_6$	$Ni_2Fe(CN)_6$	Colour developed
MN16	49·62	46·41	0·75	3·19	Bright purplish
MN17	50·43	47·15	0·80	1·62	Indigo
MN4	43·22	40·42	13·58	2·78	Good indigo blue,
MN6	44·14	41·20	13·87	0·71	very close to that
MN7	46·37	43·37	7·28	2·98	of native "Gosu"
MN3	38·76	36·25	24·37	0·62	Dull blackish blue

VII. Further correction of colour. Varying amounts of $Zn_2Fe(CN)_6$ ZnO, $FeCrO_4$ or $Zn_4(OH)_6CrO_4$ were added to the artificial "Gosu" MN7 to remove its purplish shade. Mixtures of 93·42% MN7 and 6·58% $Zn(OH)_4CrO_4$ gave a good result. The latter compound is obtained by boiling mixed solns. of $Zn(NO_3)_2$ and $K_2Cr_2O_7$. S. Kondo.

PLANT AND MACHINERY, ETC.

GYRATORY CRUSHERS AS PRIMARY BREAKERS.—W. J. Roberts (*Rock Prod.*, **26,** No. 5, 77, 1923). The advantages of gyratory crushers over other types are pointed out.

A GEARLESS, GYRATORY CRUSHER.—W. J. Cavanagh (*Rock Prod.*, **26,** No. 5, 97, 1923). An illustrated account is given of a gyratory crusher, in which the gears are replaced by a pulley.

A NEW OPEN-AIR BRICK WORKS.—(*Cer.*, **26,** 301, 1923). The arrangement of the yard, methods of transport, kiln charging and drawing, etc., are described. There are 8 illustrations.

THE SELECTION OF ELECTRIC MOTORS.—C. Saxton (*Brit. Claywr.*, **32,** 303, 1924.

A NEW MECHANICAL FUEL FEEDER.—(*Brit. Claywr.*, **32,** 312, 1924). Two sketches are given of a stoking apparatus for Hoffmann kilns invented by Clayton, Goodfellow & Co. In general principle, the machine is similar to the first design of this type, which originated in France in 1912. This consists of a slide, instead of a disc, with a diagonal slot, which moves across a fixed plate with a similar diagonal slot at an angle to the one above it.

PATENTS.

HANDLING BRICKS.—Refractories Machinery Manufacturing Co. and C. L. Norton (*Pat. J.*, 1,820, 1923). No. 205,317, Oct. 2, 1922. A machine is described which comprises means for bringing a series of pallets successively into exact alignment with corresponding moulds to receive the bricks discharged therefrom. Endless chains passing round driving sprockets carry a series of pallet holders furnished with lugs adapted to be engaged by projections on the moulds.

BRICK MOULDING MACHINES.—T. Stanley and T. S. Whitfield (*Pat. J.*, 1,828, 1924). No. 208,024, Jan. 3, 1923. A lubricating device is described. The pusher is provided with an oil receptacle communicating with feed channels holding wicks to lubricate the face of the brick.

GRINDING AND CRUSHING MILLS.—F. Krupp Akt-Ges. (*Pat. J.*, 1,831, 1924). No. 208,962, Mar. 19, 1923. In the mill described, both grinding surfaces are magnetised to increase the working pressure. A separation of the material according to its degree of magnetic susceptibility may be combined with the grinding process.

III.—FINISHED PRODUCTS: TESTING, ETC.

A COMPARISON OF BRICKS WITH CONCRETE BLOCKS.—C. Campbell (*Brick Pot. Tr. J.*, **31,** 137, 1923). More complete control is possible in the manufacture of bricks than is the case with blocks. The latter are also less able to withstand shock, and rough handling than bricks.

REFRACTORIES IN THE STEEL INDUSTRY.—J. S. McDowell (*Blast Fur.*, **11,** 522, 1923). A summary of the more important published data dealing with the properties of refractories, methods of employing them, etc., is given.

REFRACTORY MATERIALS FOR STEELWORKS.—(*Chem. Age, Metallurgical Sect.*, **10,** 10, 1924). The uses and essential properties of refractories employed in the following branches of steelworks practice are discussed: (1) The open hearth process; (2) basic and acid converters; (3) electric furnaces; (4) the crucible process; (5) regenerators, re-heating furnaces, etc.; (6) preparation of moulds.

ON SEGER CONES.—Ryoichi Shigemune. (*J. Jap. Cer. Assoc.*, **32,** No. 374, 41, 1924). A short historical survey of the manufacture of Seger Cones in Germany, U.S.A. and Japan is given. The work of H.A. Seger, H. Hecht, M. Simonis and Shepherd-Rankin, on the relation between the melting point and chemical or mineral composition, as well as that of Robert B. Sosman and Hoffmann-Meissner, on the effect of heating time upon the melting point, are then discussed. In conclusion, the author urges the specification of their manufacture in the country. S. KONDO.

THE QUALITY OF COMMON BRICK MANUFACTURED IN JAPAN.—

Sakuhei Kobayashi. (*J. Jap. Cer. Assoc.*, **32**, No. 374, 57, 1924). In Jan. 1922, the Brick Committee of the Engineering Standard Committee of the Japanese Government resolved to investigate the quality of common brick manufactured in the country and, thereafter, 115 kinds of common brick, made by 18 works, were tested in the Tokio Industrial Lab. The author summarises the results obtained by Maruta and Nakai. The conclusions are: I. The crushing strength of common bricks of the same manufacture increases as their absorption decreases. Absorption is, however, never a measure of crushing strength, when bricks made at different plants are concerned. II. The crushing strength—absorption curve indicates that Japanese brick can be classified in (1) those with crushing strengths over 350 kg., (2) those with a strength of 350–200 kg. and (3) those having a strength under 200 kg. per sq. cm.; the absorption of class (1) is less than 9% for bricks of the Western districts, while it is within 14% for those of Eastern districts; absorption of class (2) is 9–14% for Western bricks and 14–18% for the Eastern. S. Kondo.

A REFRACTORY-UNDER-LOAD TESTING MACHINE.—H. Hecht (*Tonind. Ztg.*, **48**, 109, 1924). A new machine, differing entirely from those hitherto employed for the purpose, has been devised, with the main object of eliminating all possibility of any change taking place in the load applied and in the frictional element during the test. Consequently, the principle of the balance, and all similar constructions, was ruled out from the start. The new machine, which is described by the aid of a sketch, has a crane-like appearance. It is so constructed that the load applied can be adjusted exactly to the conditions of the test; the load is applied vertically from above and can be maintained absolutely constant throughout the test, independent of any expansion due to the heating of the apparatus, or of any part thereof. For each test it is possible to determine not only the exact load to be applied, but also to restrict the collapse of the test-piece to any desired extent, so that complete destruction of the sample can be avoided. The whole apparatus can be swung round, crane-fashion, on a central support, so that if, in works practice, a large number of tests has to be made daily, it is only necessary to arrange a number of electric furnaces within the operating circle of the machine. The broad principle of the machine is as follows:—The rod, by which the load is applied, is supported by ropes passing over two pulleys, and counterbalanced. Preparatory to carrying out a test, this rod is centred vertically over the tube of an ordinary electric furnace. To apply a given load to the test-piece, the required number of counter-weights can be detached mechanically from the plate supporting the rod. The machine has been constructed in the Testing-Machine Department of the Chemical Laboratory for the Clay Industry. (H. Seger and E. Cramer), in Berlin.

CLAY BRICKS *VERSUS* SYNTHETIC BRICKS.—(*Brick*, **64**, 580, 1924). A new apparatus, perfected by the Bureau of Standards is said to expedite the testing of bricks for transverse strength and also gives more accurate results than with the method hitherto employed by the Amer. Soc. for Testing Materials. Two tables are given, showing comparative results. Clay bricks, cement bricks, and sand-lime bricks were tested by both methods. The clay bricks showed a much higher modulus of rupture than either of the other two.

BRICKS FOR ROAD PAVING.—H. Boot (*Brit. Claywr.*, **33**, 41, 1924). The advantages of bricks of suitable quality for road paving are indicated, and reference is made to the essential qualities, method of manufacture, jointing and method of laying.

IV.—MANAGEMENT, ORGANISATION, COSTING, ETC: COMMERCIAL.

NOTES ON BURNING REFRACTORIES, WITH SPECIAL REFERENCE TO THE CONTROL OF LABOUR COSTS.—L. C. Hewitt (*Bull.*

Amer. Cer. Soc., **2**, 109, 1923). The most efficient method of burning certain types of refractories is by means of the tunnel kiln, which provides a greater degree of control, gives reduced firing labour and handling costs, lower fuel consumption, quick turnover, and a higher percentage of first-quality ware. In most cases, however, no sudden change is possible from present equipment to this modern method; on some plants such factors as general lay-out, financial situation, etc., may even make such a change prohibitive. Nevertheless, greatly increased burning efficiency may usually be obtained from present equipment by slight changes in design, method of firing, type of setting, etc. Manufacturers in general are well aware of the importance of such factors as thorough drying of the ware before setting, regular inspection of flues, correct size of stack flue, kiln design, the use of the pyrometer to control the burning schedule, but the question of controlling labour costs has received much less attention. The author deals with this aspect of the subject at some length. The method of applying time and motion study to this problen is fully explained.

THE MANUFACTURE OF DINNER WARE.—(*Claywr.*, **81**, 451, 1924). A detailed and well-illustrated description is given of the equipment and operating methods employed on the Homer Laughlin China Company's new plant at Newell, W. Va., said to be the largest pottery under one roof in the world.

THE MANUFACTURE OF SEWER PIPES.—(*Claywr.*, **81**, 473, 1924). The plant of the Cannelton Sewer Pipe Co. (Ind.) is described and illustrated.

BRAZIL AS A PRODUCER AND CONSUMER OF CERAMIC PRODUCE.—A. Herborth (*Ker. Rund.*, **32**, 184, 1924). Illustrations are given of the Manufactura Nacional de Porzellanas near Rio de Janeiro, and of the articles produced at these works, including wall tiles, vases, porcelain insulators, etc., made exclusively of Brazilian raw materials. Brazil has rich deposits of china clay, felspar, quartz, marble, lime, pegmatite, magnesite, plastic clays, bauxite, etc. There are many potteries distributed over the whole country. A few brick and tile works are run on modern principles, but for the most part, primitive methods prevail. Quality and price are the dominating factors to which foreign competitors must devote their attention.

CLAY-WORKING PROBLEMS IN WESTERN CANADA.—W. G. Worcester (*Claywr.*, **81**, 230, 1924). A discussion mainly from the brick maker's point of view. The difficulties of climate, labour supply, etc., are treated.

V.—GLASS, GENERAL.

AN INSULATED FINING CHAMBER.—(*Cer. Ind.*, **2**, 271, 1924). An illustrated account of Plant No. 1 of the Atlantic Bottle Co., Tarentum, Pa., is given. A distinctive feature of the plant is the insulated fining chamber, affording great protection both to men and machinery. A 9-inch wall of insulating material is located between the flux block and the outside wall.

"DISEASED" GLASS.—O. Lindekam (*Diamant*, **46**, 219, 1924). In common with all other materials glass is subject to "fatigue," "disease" and decay due to the action of material forces. The case of York Minster is cited, where it was found that windows directly exposed to sound waves were in a much more advanced stage of "disease" than those in more remote or sheltered positions. Glass "disease," however, has not yet been satisfactorily diagnosed. The article concludes on a somewhat pessimistic note: "A limit is set to all human achievement; Nature pursues her eternal way, sooner or later bringing all things to destruction."

CLEAR FUSED QUARTZ.—E. R. Berry (*Chem. Tr. J.*, **74**, 707, 1924). Recent developments in the manufacture of clear fused quartz, and some of its properties, are dealt with. The best raw material is rock crystal which is water-clear. It is packed tightly in graphite or carbon crucibles and

quickly raised to melting point in a modified vacuum furnace. The result of the first fusion is a clear, transparent slag comparatively free from bubbles. This is placed in another graphite crucible, which is suspended in a vertical carbon tube furnace, and is again fused under pressure from a graphite piston, which just fits the crucible. By the action of the weight applied to the piston, the quartz is extended in various forms, *e.g.*, rods, tubes, ribbon, etc. For large blocks free from bubbles a somewhat different operation is necessary. As soon as the quartz is fused, the vacuum value is closed and the pressure in the tank or furnace is brought up to the required extent in less than a minute. This destroys the bubbles to a very large extent. Clear, fused quartz can be used up to 1,000°C. for many purposes. Its coefficient of expansion is extremely low. It is possible to heat a tube of clear, fused quartz ⅝ in. thick to melting-point and plunge it into ice-cold water, without fracturing. Light can be passed through great lengths of quartz rod or tubing with very little loss. A rod one metre long will emit at one end about 93% of the total visible light passed into the other end. For best grades of optical glass, the highest percentage transmitted under the same circumstances is only 65%. Heat rays are also transmitted with little loss. If one end of a fused quartz rod 12 in. long is heated to incandescence, it will be found uncomfortable to hold a finger over the other end, although the rod can be grasped confortable a few inches from the heated zone. Clear fused quartz is transparent to the ultra-violet rays, and its use by the medical profession is consequently extending. It is an ideal material for thermometer tubing, since, unlike glass, it exhibits no appreciable "lag."

ON THE WEATHERING OF BULB GLASS.—Sangoro Takanashi. (*J. Jap. Cer. Assoc.*, **32,** No. 373, 1924). In the first part, the results of experiments, in which published methods of testing glass on the chem. behaviour of its surface had been followed, are given. Four glasses, with the formulæ (1) $0{\cdot}9Na_2O{\cdot}1{\cdot}1PbO{\cdot}6SiO_2$, (2) $1{\cdot}3Na_2O{\cdot}0{\cdot}7CaO, 6SiO_2$, (3) $0{\cdot}6Na_2O, 2{\cdot}0\ B_2O_3{\cdot}6SiO_2$ and (4) $0{\cdot}8Na_2O{\cdot}0{\cdot}4K_2O{\cdot}6SiO_2$ were used in the experiments. The results were as follows:

	Loss in weight occurring when glass ground to pass through a No. 20 sieve is digested in water in an autoclave		Blooming of glass beads when heated in steam in an autoclave		Alkali taken up by 150 cc. of water, at 92_2°C. in 1 hr. per 5 gr. of glass, ground to pass through a No. 25 sieve, expressed in mg. of soda	Devitrification caused by htg. glass for 3 hrs. in an elec. fur. (5—7 hrs. were required for cooling).			
	4atm. 2 hrs.	6atm. 3 hrs.	4atm. 2 hrs.	6atm. 3 hrs.		500°C.	600°C.	700°C.	800°C.
(1)	0·04%	0·10%	None	Slight	1·52	None	Medium	Remarkable	Remarkable
(2)	0·48%	1·14%	Medium	Remarkable	7·47	None	None	Medium	Remarkable
(3)	0·60%	5·16%	None	None	15·93	None	None	None	Medium
(4)	19·35%	29·07%	None	None	48·36	None	None	None	Medium

Crystals due to weathering occur usually on the inner surface of the bulb before sealing. Glass (1) was least insusceptible to weathering, though its crystal was only removed with dil. soln. of HF. The author then describes his apparatus for testing glass on its resistance to weathering. It is a wooden box, with a door, and is heated electrically. A producer of CO_2 or other gas and a water pan or drying apparatus are attached. When glasses are exposed to the moist air of the apparatus temps. of 30°–40°C. are most favourable to

their weathering. The introduction of CO_2 accelerates it. Glass (1) has been weathered in 3–7 days in the apparatus while it required 2 months, even in the rainy season, for its testing in the ordinary atmosphere. Microphotographs are given. S. KONDO.

COLORING ACTION OF BISMUTH ON GLASS.—Kitsuzo Fawa. (*J. Jap. Cer. Assoc.*, **34**, No. 373, 5, 1924). 282 batches of various glasses were melted to find the influence of their chem. composition on the colouring action of Bi compds., with or without the addition of oxydising or reducing agents. The chem. formulæ of the glasses were $R_2O \cdot R''O \cdot 3SiO_2$ and $R_2O \cdot R''O \cdot 0{\cdot}5B_2O_3 \cdot 3SiO_2$, where R′ and R″ represent Na or K and Ca, Mg, Zn, Ba or Pb respectively. I. Basic carbonate of Bi, $2(BiO)_2\,CO_3 \cdot H_2O$. 2·5–5% of the carbonate impart a colour which varies from grey to brown for most glasses, while the other remain colourless. Generally speaking, the colour is lightest in borosilicate glasses and darkest in non-boron potash glasses. Reheating favours the brown coloration, sometimes opacifying the glass. These changes occur usually on the surface in borosilicate glasses. The brown or grey coloration of Bi glasses may be attributed to the formation of colloidal Bi. II. Bi subnitrate, $Bi(OH)_2NO_3$. The coloration is generally weaker than in I, but the difference disappears on reheating. III. Basic carbonate of Bi and K nitrate. The addition of an oxydising agent, such as potassium nitrate, reduces the coloration, the tendency being observed even after reheating. IV. Basic carbonate of Bi and K tartarate. The reducing agent has little influence upon the action of the carbonate. V. Basic carbonate of Bi and arsenious acid. 0·5–1·0% of arsenious acid added to the batches prevents the glasses from being coloured by the Bi carbonate, though the influence is reduced by reheating. S. KONDO.

COLOUR IMPARTED TO GLASS BY STANNIC OXIDE.—Kitauzo Fuwa. (*J. Jap. Cer. Assoc.*, **32**, No. 373, 18, 1924). The amounts of stannic acid required for opacifying various glasses are given.

Formula of glass	Stannic acid added. %	Appearance of glass	Appearance after reheating
1 $3Na_2O.CaO.6SiO_2$	25	Transparent	Transparent
1 $3K_2O.CaO.6SiO_2$	30	,,	,,
1 $3Na_2O.MgO.6SiO_2$	20	Light bluish and opal	Light bluish and opal
,,	30	Opal	Opal
1 $3K_2O.MgO.6SiO_2$	10	Like Alabaster	Like Alabaster
1 $3Na_2O.ZnO.6SiO_2$	25	Transparent	Transparent and iridescent
1 $3K_2O.ZnO.6SiO_2$	40	,,	,,
1 $3Na_2O.BaO.6SiO_2$	25	,,	Transparent
,,	30	White and opaque	White and opaque
1 $3K_2O.BaO.6SiO_2$	30	Transparent	Slightly iridescent
1 $3Na_2O.PbO.6SiO_2$	20	Greenish and opaque	Grey at surface
1 $3K_2O.PbO.6SiO_2$	20	Opaque	Opaque

S. KONDO.

GOVERNMENT (U.S.A.) SPECIFICATION FOR GLASS TABLEWARE.—(*Glass Ind.*, **5**, 79, 1924). Details are given of Standard Specification No. 121, officially adopted for the U.S.A. War Departments. The requirements as regards colour, design, methods of testing, etc., are outlined. The boiling test is as follows: The articles are completely immersed in a suspended position, in distilled water contained in a closed vessel having a small steam vent, and boiled continuously for 6 hours. They are required to show no corrosion, scumming, chipping or cracking as a result of this test. Shock test: Immersion in cold water (16-21°C.) for ten minutes followed by

sudden transfer to boiling water. Five repetitions must not cause cracking.

JENA GLASS.—Thiene (*Glass Ind.*, **5**, 81, 1924). Translated from the *Ker. Rundschau*. A brief sketch of the historical development of the Jena Glass Works is given, together with a short survey of the various types of glasses manufactured there.

SODIUM NITRATE AND CALCIUM SULPHATE AS SUBSTITUTES FOR SALT CAKE IN PLATE AND SHEET GLASS.—(*Glass Ind.*, **5**, 89, 1924). The U.S. Patent, No. 1,488,914, issued to F. Gelstharp on 1 April, 1924, is descussed. This patent, which has been assigned to the Pittsburgh Plate Glass Co., relates mainly to the means employed in "fining" glass, the basic batch being practically unaltered. In the old process, "fining" was brought about by the decomposition of the salt cake together with the action of the charcoal and the reducing atmosphere. The finished glass contained an undue amount of very fine bubbles or seeds, due more or less, according to G., to deferred decomposition of a small portion of the salt cake. Analysis of this glass always shows about 0·7 to 1·0% of salt cake. In the improved process, salt cake is not used as a "fining" agent, but simply as an agent to eliminate the scum characteristic of lime glass. The "fining" action is secured from the reaction between sodium nitrate and white arsenic, the nitrate supplying oxygen to effect the change from As_2O_3 to As_2O_5. Calcium sulphate may be used to replace the salt cake entirely.

THE SOLUBILITY OF HELIUM AND HYDROGEN IN HEATED SILICA GLASS AND THE RELATION OF THIS TO THE PERMEABILITY.—G. A. Williams and J. B. Ferguson (*J. Amer. Chem. Soc.*, **46**, 635, 1924). The authors determined the solubility of helium and hydrogen gases in silica glass at two temperatures. The solubility of helium in Pyrex glass was also obtained for the temperature. The permeability of silica glass to helium is many times greater than the permeability to hydrogen, though in theory, they should be as 7 to 10. The solubilities of He and H differ but little, and hence do not explain this marked difference. The relation between temperature and permeability is shown to be similar for many of the cases investigated. The phenomenon in general is discussed.

THE DEPARTMENT OF GLASS TECHNOLOGY, SHEFFIELD, ENGLAND.—W. E. S. Turner (*Glass Ind.*, **5**, 39, 1924). A brief, illustrated account is given of the new premises and apparatus.

MECHANICAL TESTS ON GLASS, ETC.—G. H. Dacy (*Glass Ind.*, **5**, 46, 1924). An account is given of the methods and apparatus employed by the Bureau of Standards to test glass and chinaware for durability and service. One machine (illustrated) is capable of exerting a pressure of 100,000 lb. A water pressure system is used to simultate wind pressure.

NOTES ON COATING (FLASHING) GLASS.—L. Appert (*Verre*, **4**, 49, 1924). The theory and practice of coating glass (with a film of glass of another colour, with metals, etc.) are discussed. Six conditions are cited in conclusion, which, if carefully observed, will ensure the success of the coating operation.

SURFACE CHANGES OF GLASS; PHENOMENA DETECTED BY HIGH-TENSION ELECTRIC CURRENTS.—P. Woog (*Verre*, **4**, 54, 1924). On measuring the electric strength of a hydrocarbon in a glass vessel, the surface of the liquid often appears agitated, due to the passage of the high-tension current over the surface of the glass, the latter being a relatively better conductor for the high voltage employed. The apparatus employed to study this phenomenon is described. It was found that the presence of water had a marked effect on the voltage necessary to produce a discharge. If the glass vessel is not perfectly dry, and the oil completely anhydrous, the voltage falls considerably and progressively. Figures are given showing the effect of temperature on the voltages. This property of the glass is held to be caused by efflorescence on the surface of the vessel, bases being liberated

by hydrolysis of the silicates. Atmospheric CO_2 then forms a thin film of sodium carbonate on the surface of the glass. If water is present, this salt, which contains 4 or 5 mol. of water at ordinary temperatures, is transformed on cooling into the hydrate with 10 H_2O. Efflorescence then takes place on reheating, when the vapour pressure of the hydrate is no longer in equilibrium with that of the water contained in the liquid. By utilizing this variation in the hydration of glass, it is possible to detect a water-content in hydrocarbons of less than 1/60,000.

PATENTS

ORNAMENTING GLASSWARE.—E. J. Kiefer (*Pat. J.*, 1,836, 1924). No. 210,754, Jan. 14, 1924. A machine for cutting designs in glassware, *e.g.* tumblers, is described.

CUTTING GLASS.—A. Molina (*Pat. J.*, 1,837, 1924). No. 210,788, Jan. 31, 1924. An appliance for cutting the ends of glass tubes, etc., is described.

DELIVERING MOLTEN METAL.—W. J. Miller (*Pat. J.*, 1,837, 1924). No. 210,818, Oct. 3, 1922. The automatic feeding device described comprises means (*a*) for successively discharging gobs of metal from the tank into a shaping receptacle; (*b*) discharging each formed gob from the receptacle in a mould of the forming-machine, and (*c*) for serving the neck connecting the gob with the metal in the tank.

BLOWING AND GATHERING GLASS.—Soc. Anon. d'Etudes Constructions d'Appareils Mécaniques pour la Verrerie (*Pat. J.*, 1,845, 1924). No. 213,576, Mar. 25, 1924. An automatic machine for forming glassware is described.

ROLLING GLASS.—F. Riechers (*Pat. J.*, 1,846, 1924). No. 214,218, Mar. 20, 1924. Relates to rolling machines, the purpose of the invention being to avoid wastage of the glass sheet.

ROLLING GLASS.—A. Elliot (*Pat. J.*, 1,846, 1924). No. 244,219, Mar. 20, 1924. An arrangement is shown for preventing undue cooling of the sheets during their passage from the machine to the lehr.

MAKING PLATE GLASS.—A. Elliot (*Pat. J.*, 1,846, 1924). No. 214,220, Mar. 20, 1924. In the process described, the whole content of a pot is tipped in one charge into a rolling machine having one or more pairs of rollers. A cover plate is provided to cover completely the receiver on to which the molten glass is tipped, and also to cover the rollers.

DRAWING GLASS.—E. Rowant (*Pat. J.*, 1,841, 1924). No. 212,545, Mar. 1, 1924. In the arrangement shown, the body of the sheet and its edges are drawn from independent supplies of glass.

MARKING GLASS BULBS.—D. K. Wright (*Pat. J.*, 1,842, 1924). No. 212,938. A method of marking an electric bulb during the process of making the lamp is described.

GLASS ANNEALING LEHR.—H. L. Dixon Co. (*Pat. J.*, 1,843, 1924). No. 212,997, Dec. 21, 1922. An annealing lehr for plate glass is formed with an oven portion in line with the cooling tunnel, and mechanical means are provided for advancing the plates through the oven into the tunnel.

FORMING SMALL BULBS.—J. C. Cowlishaw, Mather & Platt, Ltd. (*Pat. J.*, 1,844, 1924). No. 213,375, Jan. 31, 1923. A device is shown for blowing a bulb at the end of a capillary tube.

DELIVERING MOLTEN GLASS.—J. T. Wood (*Pat. J.*, 1,844, 1924). No. 213,406, Mar. 6, 1923. A forehearth forming part of an automatic feeder is described.

GLASS ROLLING.—Ford Motor Co. (*Pat. J.*, 1,839, 1924). No. 211,775, June 12, 1923. The production of sheet glass in a continuous strip (Spec. 196,293) is referred to. Means are provided for keeping the width of the strip constant.

GATHERING MOLTEN METAL.—Soc. Anon. d'Etudes et de Constructions d'Appareils mécaniques pour la Verrerie (*Pat. J.*, 1,840, 1924). No. 211,852, Feb. 1, 1924. A machine for forming wide-mouthed ware is described.

REFINING GLASS; MAKING ELECTRIC LAMPS.—L. S. Vello (*Pat. J.*, 1,840, 1924). No. 211,879, Feb. 21, 1924. Apparatus is described for removing occluded gases from the glass in the process of sealing electric lamp bulbs by fusing in a vacuum. Spec., 197,693 is referred to.

DELIVERING MOLTEN GLASS.—K. Michaelis (*Pat. J.*, 1,841, 1924). No. 212,250, Feb. 26, 1924. Relates to the manufacture of plate glass, more particularly to the method of casting the contents of a pot on to the rolling table.

DELIVERING MOLTEN GLASS.—C. H. Rankin (*Pat. J.*, 1,841, 1924). No. 212,494, Oct. 1, 1923. An arrangement of the forehearth, whereby the stream of metal is taken from below the surface of the metal in the tank, is shown.

TANK FURNACE.—H. Michotte (*Pat. J.*, 1,839, 1924). No. 211,730, Mar. 20, 1923. The tank, from which sheet-glass is drawn, is heated on two sides only. It is connected with the main furnace by a passage, and on each side is a heating chamber.

BENDING GLASS TUBES.—G. Claude and J. M. E. de Beaufort (*Pat. J.*, 1,835, 1924). No. 210,404, Dec. 10, 1923. A suitable electric resistance wire is wound round the tube, current is passed through until the glass is soft, and the tube is then shaped on a template.

FORMING SILICA-GLASS ARTICLES.—Brit. Thomson-Houston Co. (*Pat. J.*, 1,836, 1924). No. 210,707, Sept. 25, 1923. Articles made from transparent quartz, which has been extended through an orifice in a graphite container, have been found to contain striæ. According to the invention, the surface layer of the quartz is removed, before it is worked up, by mechanical means, or by hydrofluoric acid.

ANNEALING LEHRS.—G. G. Oliver and J. Stenhouse (*Pat. J.*, 1,836, 1924). No. 210,721, May 7, 1923. A method of conveying glassware through an annealing lehr on suspended carriers is described.

FORMING SILICA GLASS ARTICLES.—Gen. Electr. Co. (*Pat. J.*, 1,830, 1924). No. 208,682, Sept. 12, 1923. Relates to the production of tubes from fused quartz. Cane, or strip quartz is wound while plastic on a mandrel, so that adjacent coils are in close proximity. Pressure is applied to the coils while still plastic to cause them to coalesce.

GRINDING GLASS PLATES.—Pilkington Bros. and F. B. Waldron (*Pat. J.*, 1,832, 1924). Nos. 209,142 and 209,152, Sept. 25, and Oct. 2, 1922. A machine for the continuous grinding of glass plates is described. The sliding friction between the tables and the guides is replaced in part by rolling friction.

DELIVERING MOLTEN GLASS.—Rylett's London Secretariat and A. McNish (*Pat. J.*, 1,832, 1924). No. 209,221, Oct. 19, 1922. The device described consists of a pair of mechanically operated tongs carrying the shear blades.

ROLLING GLASS.—F. Reichers (*Pat. J.*, 1,833, 1924). No. 209,417, Jan. 2, 1924. Means are provided for heating the table of a double-roll machine in a furnace before it is moved forward to receive the sheet, the main object being to evaporate any absorbed moisture from the table, which is made of refractory bricks.

GLASS-ANNEALING LEHR.—H. L. Dixon Co. (*Pat. J.*, 1,828, 1924). No. 208,014, Dec. 21, 1922. The muffle portion is formed in the roof of the lehr, with a number of longitudinally extending flues, each having combustion means associated therewith.

GLASS MANUFACTURE.—O. M. Tucker, W. A. Reeves and J. M. Beatty

(*Pat. J.*, 1,829, 1924). No. 208,172, Dec. 10, 1923. A device for feeding charges of glass to a forming-machine is described.

FORMING ELECTRIC LAMP BULBS.—Patent Trenhand Ges. (*Pat. J.*, 1,830, 1924). No. 208,491, July 30, 1923. The mould consists of a flat plate, formed with a moulding hole, into which leads a channel to receive the glass tubing.

ELECTRIC INSULATORS OF FUSED QUARTZ.—Gen. Electr. Co.—(*Pat. J.*, 1,830, 1924). No. 208,667, Feb. 22, 1923. An electrically heated carbon core is immersed in quartz grains until an incrustation of fused quartz of the desired thickness is obtained. The core is removed by drilling. A hollow end is formed by sealing the shell at one end by heat and expanding under air-pressure.

VI.—CEMENT, CONCRETE, MORTARS, ETC.

ON THE PROPERTIES OF CEMENTS FOR PAVING.—Kuichi Koyama. (*J. Jap. Cer. Assoc.*, **31**, No. 373, 400, 1924). The Japanese Specifications for Portland cement are criticised in relation to its use in paving. Italian Soliditit cement, analysing as silica 34·27, alumina 11·87, ferric oxide 5·00, lime 42·40, magnesia 0·68, potash 0·51, soda 2·99, sulphuric anhydride 1·38, sulphur 0·01 and loss on ignition 2·80% was used in some experimental roads in Tokio and Osaka. The result is not yet reported. S. Kondo.

INVESTIGATION ON PAVING MATERIALS BY THE CITY OF OSAKA.—Sai Takaoka. (*J. Jap. Cer. Assoc.* **31**, No. 373, 397, 1924). Descriptions of the present state of road paving in Osaka City and the equipment of the City Lab. for Engineering Research are given. S. Kondo.

RECENT STUDIES ON CONCRETE IN THE U.S. AND THE WORK OF PROF. ABRAMS.—(*Génie Civil*, **83**, 89, 1923).

WATER-PROOF CONCRETE.—O. Graf (*Tonind. Ztg.*, **48**, 33, 1924). A brief review of recent German literature on the subject.

CALCIUM SULPHATE CEMENT.—C. L. Haddon and M. A. W. Brown (*J. Soc. Chem. Ind.*, **43**, 11T, 1924). The main objects of this research were: (1) To determine the number of allotropic modifications of anhydrous calcium sulphate; (2) to explain differences in setting properties of calcium sulphate from different sources; (3) to examine the acceleration of setting by other sulphates; (4) to investigate the nature of intercrystalline adhesion from the evidence obtainable from calcium sulphate cement. The conclusions are tabulated.

HINTS ON THE PREPARATION AND SUPPLY OF BLAST FURNACE SLAG AS AN AGGREGATE OF CONCRETE AND FERRO-CONCRETE.—(*Stahl Eis.*, **44**, 590, 1924). Report of a Committee appointed to investigate the uses of blast furnace slag in January, 1924.

THE ELECTRICAL PRECIPITATION OF DUST IN THE CEMENT INDUSTRY.—H. Nitzsche (*Tonind. Ztg.*, **48**, 517, 1924). The electrical precipitation of dust and other impurities from gases or vapours is brought about by the ionisation of the gas which takes place when it is passed between two electrodes through a high-tension field of about 50,000 volts. The gas ions then become attached to the dust particles, forcing them to collect on the electrode, from which they fall when the deposit reaches a certain thickness. The methods of applying the system of electrical purification of gases to the cement industry are briefly outlined. (12 illustrations).

PATENTS.

SLAG CEMENTS.—H. Andrews (*Pat. J.*, 1,839, 1924). No. 211,517. Lime with or without silica and iron ore, etc., is mixed with molten blast furnace

slag and fed into a rotary kiln at 1,500°C. Waste gases from the kiln are used to burn limestone for the production of the lime. The clinker is ground with or without an addition of 30-50% of granulated slag.

MOULDING CONCRETE.—W. Hopkins (*Pat. J.*, 1,840, 1924). No. 211,948, Nov. 29, 1922. Relates to jigging-machines for consolidating and moulding concrete.

POROUS CONCRETES.—J. A. Eriksson (*Pat. J.*, 1,841, 1924). No. 212,419. Mar. 13, 1923. The composition consists of Portland cement, "slate-lime" (mixture of calcined slate and lime), and a powdered metal, such as zinc or aluminium, capable of generating gas in the presence of water. The water used for mixing should be heated to 25–40°C. To accelerate hardening, sodium carbonate, gypsum, or "ciment fondu" may be added.

MOULDING CONCRETE PIPES.—V. Maggio (*Pat. J.*, 1,837, 1924). No. 210,872, Nov. 8, 1922. Description of apparatus for moulding concrete pipes, columns, etc., with mould and presser fitted with helical parts. Comprises a presser of cylindrical form with segments removed to provide longitudinal limbs separated by apertures which serve for the introduction of the material into the mould.

MOULDING CONCRETE BLOCKS.—H. McKinnon (*Pat. J.*, 1,838, 1924). No. 211,333, Feb. 3, 1923. Moulding and pressing apparatus is described.

PROCESSES FOR MAKING PORTLAND CEMENT, ETC.—R. Décolland (*Pat. J.*, 1,839, 1924). No. 211,497, Feb. 14, 1924. Aluminous cements are made in ordinary rotary kilns by (*a*) lengthening the heating-zone ; (*b*) preventing the formation of a coating of fused fuel ashes. The first is accomplished by employing a fuel such as lignite, containiug a large proportion of volatile neutral products, or by diluting the kiln atmosphere with water vapour, etc. ; (*b*) is attained by mixing limestones with the fuel, to combine with the silica, iron, etc., and render the ash refractory.,

MOULDING CONCRETE PIPES.—J. A. Davidson (*Pat. J.*, 1,820, 1923), No. 205,263, Aug. 10, 1922. Relates to centrifugal machines.

MOULDING CONCRETE PIPES.—C. W. Baines and Stanton Ironworks Ltd. (*Pat. J.*, 1,828, 1924). No. 208,058, Feb. 27, 1923. Relates to the construction of the mould.

REINFORCED CONCRETE PIPES.—Internationale Siegwastbalken Ges. (*Pat. J.*, 1,831, 1924). No. 208,958, Mar. 9, 1923. Reinforcement by longitudinal iron rods and circumferential wire netting is described.

TESTING PORTLAND CEMENT.—W. L. H. Roberts (*Pat. J.*, 1,835, 1924). No. 210,154, Oct. 25, 1922. Marl, or chalk is calcined at 2,300°F., passed through water, stored until it falls to powder, and mixed with Portland cement either before or after the final grinding.

BAUXITE CEMENT.—L. G. Patrouillean (*Pat. J.*, 1,835, 1924). No 210,366, July 23, 1923. Bauxite cements are freed from metallic impurities by treatment in a magnetic separator after manufacture. By this means, a constant proportion of lime, alumina, silica may be obtained.

IMITATION STONE.—R. F. Wilkins and H. Chandler (*Pat. J.*, 1,836, 1924). No. 210,470, Aug. 4, 1922. A composition to be applied to walls to give the appearance of stone consists of 50% freestone dust or other fine clean sand, 25% white cement, 20% silver sand, and 5% of a compound containing hydrated lime, fat, and alkaline carbonates, the whole being mixed into a paste with a concentrated aqueous solution of ¼ oz. iron sulphate and 1 oz. alum, to which ¼ pint of spirits of salt has been added.

OXYCHLORIDE CEMENT.—A. Petelot (*Pat. J.*, 1,836, 1924). No. 210,760, Jan. 22, 1924. The cement, which resembles stone, marble, or pottery, is a mixture of zinc sulphate, barium chloride, ammonium chloride, zinc oxide, and silica, with or without limestone. The first 3 ingredients,

diss. in water, and part of the zinc oxide are mixed together, evaporated to dryness, and heated to 340°, the remaining components being added after cooling.

MAKING CONCRETE PIPES, POLES, ETC.—T. G. O. Hyden and E. V. Carlsson (*Pat. J.*, 1,844, 1924). No. 213,554, Mar. 12, 1924. The method described consists in effecting the filling of the mould and distribution and compression of the material by relative movement of the mould and core.

MOULDING CONCRETE BLOCKS.—A. E. Worsley (*Pat. J.*, 1,847, 1924). No. 214,359, Feb. 1, 1923. Two forms of moulds for concrete or clay blocks, bricks, etc., are shown.

MAGNESITE CEMENT.—B. Bakewell (*Pat. J.*, 1,847, 1924). No. 214,369, Feb. 6, 1923. A cement which does not corrode iron is made by adding ferrous chloride to magnesium oxide, the proportions being at least 30 parts of the crystalline chloride to 100 parts magnesia. Fillers such as asbestos, sand, cork, may be added. Example: 100 parts magnesia, 45 parts cryst. ferrous chloride, 15 parts cork, and 62 parts water.

VIII.—HISTORICAL, EDUCATIONAL, INSTITUTIONS, ETC.

SILICOSIS IN THE REFRACTORIES INDUSTRIES.—(*Quarry*, **29**, 67, 1924). A discussion of the first report of the Departmental Committee on compensation for silicosis, dealing with the Refractories Industries (Silicosis) Scheme, 1919, issued as a White Paper.

EARLY CHINESE POTTERY AND PORCELAIN.—W. Burton (*Nature*, **113**, 524, 1924). A review of the book: "The Art of the Chinese Potter from the Han Dynasty to the End of the Ming," by Hobson and Hetherington.

DISCUSSION ON CLAY-WORKING PROBLEMS.—Various (*Claywr.*, **81**, 229, 1924). Papers were read and discussed by the National (American) Brick Manufacturers' Association dealing with: Clay-working problems in W. Canada; Schools for bricklayers; Standardisation and specifications; Unification of commodity specifications; Cheaper production through executives and subordinates; Exact *versus* rule-of-thumb methods in manufacture; Plant construction and equipment; Burning bricks with oil; Mechanical handling of bricks; Brick statistics; Utilization of pebbly clays; Kilns and firing.

SHAPE OF CLAY WARES AND THEIR ETYMOLOGY.—Shinzo Osuka. (*J. Jap. Cer. Assoc.*, **32**, No. 373, 21, 1924). The author has long investigated the etymology of Japanese and Chinese words for ceramic wares. Some of the results are given, with many illustrations. S. Kondo.

REVIEWS.

The Chemistry and Physics of Clay and other Ceramic Materials.

By A. B. Searle. (Ernest Benn, 1924, pp. xiii. and 696. Price 55/-)

In the Preface to this imposing volume, the author indicates the obvious truth that "only those, who have devoted special attention to the subject, can be aware of the importance of the applications of both chemistry and physics to the industrial uses of clays and other ceramic materials." He goes on to state that "such applications are so extensive, that it is remarkable that no volume has been previously published, in which they are dealt with in a systemmatic manner." Surely, after a consideration of the present state of our knowledge of clays and allied materials, it does not appear remarkable that most workers in this particular branch of applied science realize their inability to cope with the extensive field presented in the scope of the work under review, and further, recognise their lack of sufficient critical appreciation to sift the grain from the chaff in the vast assemblage of ceramic literature. However, it would appear that Mr. Searle has taken his courage in both hands, and by so doing, his effort has resulted in the production of a work which is more likely to mislead than to instruct the greater number of those into whose hands it may fall.

The scientific treatment of the subject can only be described as lamentably inaccurate. In parts we are treated to amazing discussions on elementary chemistry and physics. Thus, we find on p. 302, the statement that "intermediate between a mixture and a chemical compound are solid solutions, the properties of which are partly those of a chemical compound and partly those of a mixture." Again, on p. 302, we note that "molecular compounds are somewhat analogous to solid solutions and some solid solutions may be molecular compounds." Assuredly, Mr. Searle owes serious students of chemistry an apology for the statement,—"Hydration or hydrolysis, which consists in the addition of one or more molecules of water to a substance, is an important result of weathering" (p. 507). The book essays a discussion of the phase rule, wherein we are told, after an attempted reasoning, that in the system ice, water, steam, under no conditions can all three phases exist simultaneously in equilibrium. Again, there are few chemists who would agree with the author that the two chain formulae—one due to Mellor and Holdcroft, the other to Haushofer—given on p. 348 are similar. These are but a few of the many misconceptions and inaccurate statements, which occur in the more fundamental portions of the work. It is surprising, therefore, to read in the preface "that several subjects of purely academic interest—such as the quantum theory and entropy—have been purposely omitted,....."

The author has obviously made an effort to satisfy the requirements of the manufacturer and user of clay and allied products, yet similar inaccurate statements, redundancies and misconceptions mar the aspect of this portion of the book. Many such worthless statements are worded with such dogmatic assurance that the fault is rendered much more harmful. In this connection, we note that on p. 78 "Glasshouse pots should have a coarse and porous structure"; on p. 399, "Silica bricks should be made from rocks containing, at least, 97 per cent. silica. If the impurity is in the form of clay, as in ganister, a silica percentage of only 90 per cent. may not be harmful"; on p. 34, "Satisfactory crystalline structures have almost negligible coefficients of expansion."

In many places, Mr. Searle has given full rein to his sense of humour. For instance, there is something decidedly empirical about the definition on p. 494, viz., "Brittleness is the property possessed by some materials which causes them to break or "split" when allowed to fall on a hard floor." Again, there can be no doubt that "in order to prevent the reaction of furnace lining, crucible, or other refractory material with its contents, it is essential to use materials which will not be affected." (p. 433). The study of "Heat" is rendered iudicrous by such a definition as "Heat is the property, possessed by matter of creating a certain well-known sensation in the nerves, by means of which the substance is recognized as hot, warm, cool or cold" (p. 508).

The book might have been of decided value as a guide to ceramic literature. Such a value has, however, been nullified by the author's mistake of giving in many instances, only partial references—in some cases, we find but the names of the authorities. This is, surely, a fatal mistake, particularly when the ambitious nature of the book is considered.

The task of collecting and collating the physical and chemical data of ceramics still remains with us, and it is hoped that the next effort will show a full realization of the very great difficulties of the work and of a sound critical appreciation of the technology of clay and allied products.

A. T. Green.

"Chemists and their Work," by Stephen Miall. "Fire Chemicals," by T. W. Jones, B.Sc. "Wood Products," by T. W. Jones, B.Sc. "The Quest for Colour," by A. T. Mouilpied, B.Sc. (Lond.) M.Sc. (Vict.), Ph.D., F.I.C. "The Heavy Chemical Industry," by Rex. Furness. "Chemistry in the Manufacture of Pigments, Paints and Varnishes," by C. A. Klein, M.Sc. "Chemistry in Relation to Food," by C. A. Monier-Williams, M.A. (Oxon.), Ph.D. (Freiburg), F.I.C., O.B.E. "The Fermentation Industries," by Rex Furness.

(Ernest Benn, London, Price 6d. each).

These pamphlets are issued under the joint guidance of the Society of Chemical Industry and the Association of British Chemical Manufacturers. They are written for popular interest and enjoyment, with the further object of enlightening the public as to the work of the chemist for the community. The task has been well conceived and carried out, for, without exception, all the essays reach a high standard as literary efforts. Although no pamphlet is definitely concerned with clay, students of ceramics will derive considerable pleasure and enlightenment from the perusal of these essays.

A. T. Green.

Abstracts.

1.—RAW MATERIALS.

OCCURRENCE, PREPARATION, ETC.

THE GYPSUM DEPOSITS OF SOUTH-WESTERN PERSIA.—J. V. Harrison (*Econ. Geol.*, **19**, 259, 1924). The extent of the deposit is indicated by sketch maps. It extends over 1,000 miles along the eastern shores of the Persian Gulf to beyond Mosul in Mesopotamia. The object of the paper is to record field observations in S.W. Persia, with special reference to the light they throw on the origin of the gypsum deposits.

ANALYSIS OF CHINA CLAY BY WASHING.—(*Chem. Age, China Rev. Sect.*, **10**, 14, May 17th, 1924). The Bollenbach and Nöbel modifications of the Schulze apparatus are described and illustrated. Schöne's apparatus is dealt with at greater length and its advantages are pointed out.

PATENTS

PURIFYING CLAY.—L. A. Holden (*Pat. J.*, 1848, 1924). No. 204,699, Jan. 19, 1923. To remove the brown coloration from china clay, the latter is suspended in a solution of sodium or other alkaline sulphide, dilute H_2SO_4 being then added until the mixture is almost neutral. After 5 or 6 hours, a further quantity of H_2SO_4 is added to dissolve out ferrous sulphide formed, and to precipitate the clay, which is then washed.

SILICA.—Eliktro-Osmose Akt. Ges. (*Pat. J.*, 1,849, 1924). No. 215,011. Apr. 26, 1924. Amorphous silica is precipitated by the action of an inorganic acid and water on water-glass. The quantity of the acid must be such as to neutralise half of the soda in the water-glass, and the total volume of the reaction mixture should be from 1·5 to 2 times the vol. of the water-glass. The jelly is allowed to stand 15-20 hours and is then washed by decantation or in a filter press.

IMPROVEMENTS IN, OR RELATING TO, THE BLEACHING OF KAOLIN AND THE LIKE.—R. F. B. Gaudin and The Dartmoor China Clay Co., Ltd., Brit., Pat. No. 218,747, Apl. 12, 1923. The bleaching process is based on the proposal to bring the powdered kaolin, or other white mineral, in water into contact with pieces of metal, such as zinc, and sulphurous acid. Means are described for carrying such a process into effect successfully.

PHYSICAL AND CHEMICAL PROPERTIES, TESTING, ETC.

ON THE DETERMINATION OF THE PLASTICITY OF CLAYS AND KAOLINS.—K. Pfefferkorn (*Sprech.*, **57**, 297, 1924). E. Wilson and P. Hall suggested that figures should be obtained for each clay tested indicating (1) the quanity of water required to render the clay "workable," and (2) the resistance offered by test pieces to deformation under low pressures. The author considers these two factors of vital importance, and he reports that he has worked out a method which has given satisfactory results in practice. His measurements are based simply on the fact that, the more plastic a clay, the more water it requires to render it workable, and, *per contra*, the less plastic a clay, the less water required. The principle of the method employed is as follows. A cylindrical test-piece of plastic clay is deformed under a falling iron disc, and, at the same time, the water-content of the clay from which the sample was prepared, is determined. The water-content is then varied, the deformation tests being carried out under the same conditions as before. The relationship between the original height of the test piece (h) and the height of the same piece after deformation (h_1) is plotted against the water-content to give a series of curves. Tests were carried out on three

clays, one china-clay and an earthenware body. No. 1 was a short clay from Löthain ; No. 2 a highly plastic earthenware clay ; No. 3 a plastic earthenware clay ; No. 4 a Zettlitz kaolin, and No. 5 an earthenware body. In the tabulated results, the above relationship is designated a, that is, $h/h_1=a$. In all the tests, h was maintained constant, viz. : 40 mm. The water-content of the plastic clay was determined by drying at 110°. As an example of the results obtained, the figures for the Zettlitz china clay (No. 4) may be cited :

Per cent. H_2O	h_1 in mm.	a	Workability of the mass.
36·9	6·7	5·97	Sticky
35·6	8·0	5·00	Workable with
35·2	8·5	4·71	difficulty
32·9	14·5	2·76	Easily
32·6	16·4	2·43	workable
31·6	18·5	2·16	Workable with diff.
30·9	20·8	1·92	Too dry
29·5	25·5	1·56	Too dry

The results indicate that, for each of the clays examined, there is a zone of good workability, in which the value of a varies between 2·5 and 4·0. If a is less than 2·5, the clay is too dry to be properly mouldable ; if above 4, the clay begins to be too sticky. The water content of a plastic body, however, varies within the workability zone (where a varies from 2·5 to 4·0) ; hence, the mean between these two positions on the curves (where $a=3·3$) is marked off and the water-content corresponding to this point is taken as the *plasticity number* of the particular body being tested. Arranged in descending order, the plasticity numbers for the five clays examined by the author, were as follows : Clay No. 2, 34·0 ; Zettlitz kaolin, 33·6 ; clay No. 3, 28·0 ; Clay No. 1, 26·6 ; Earthenware body 23·2. The earthenware body, which was the shortest of all, also required the least amount of water to render it plastic, whilst clay No. 2 and the Zettlitz china clay, both highly plastic, required the least water. On adding quartz in the form of fine sand to the plastic clay No. 2, and to the Zettlitz china clay, the following figures were obtained :—

Clay No. 2 with 20% of fine sand	30·4
Zettlitz china clay with 35% ,, ...	28·8
Clay No. 2 with 45% ,, ,, ...	24·9

The five clays had the following composition :—

	Clay No. 1	Clay No. 2	Clay No. 3	Zettlitz china clay	Earthenware body
Clay substance	70·2	90·6	87·9	94·2	53
Felspar ..	3·7	2·0	3·4	1·8	12
Quartz ..	26·1	6·4	8·7	4·0	33

The method may be summarised as follows : With the clay to be tested, prepare three or four plastic mixtures containing varying quantities of water. From each mixture, make a cylindrical test-piece and "deform" it in the machine. Then plot the water contents (ordinates) against the values for a (abscissæ), and read off the water-contents corresponding to the point $a=3·3$. The figure thus obtained may then be taken as a measure of the plasticity of the clay.

OXIDATION OF CLAYS IN FIRING.—(*Claywr.*, **81**, 476, 1924). Research work on the effect of absorption of sulphur gases by ferric oxide in clays, when clayware is being fired in the kiln, has been completed by the U.S. Bureau of Mines. The changes in the amount and nature of sulphur absorbed at different temperatures were accurately determined. It was found that, with an increase in temperature up to 450°C., about half of the ferric oxide changed to ferric sulphate, a soluble salt which may cause scumming. At higher temperatures some of this ferric sulphate and most of the remaining iron combine with sulphur in an insoluble form. The work is part of a general study of the oxidising effects of various impurities present in different clays, and coals used for fuel, on the quality of the ware. The object is to determine what substances are responsible for bloating, shrinkage, warping and discoloration .

II. MANUFACTURING PROCESSES:

GENERAL.

BRICKS FROM BLAST FURNACE SLAG.—(*Chem. Age*, **11**, *Metall. Section*, Aug. 2, 1924, p. 11). The utilization of waste blast-furnace slag in the making of bricks, which has long been in use on the Continent, has been almost entirely neglected in England. The slag, in a roughly pulverised condition (or disintegrated by running the molten slag into cold water) is mixed with 6-10% of thoroughly slaked lime. Success depends upon the lime being slaked to such an extent that no unslaked lime remains. Accordingly, a special type of hydrate is used (described). The green bricks are subjected for 5-6 hours to steam at atmospheric pressure (*i.e.*, 212°F.), the chief chemical reaction being a combination of the free SiO_2, or acid silicates of the slag with the lime, forming calcium silicates, which bind the mass together, giving intensely hard bricks. The crushing strain is about 4,800 lb. per sq. inch.

GLADDING, McBEAN AND CO.'S PLANT AT SAN FRANCISCO.—(*Brick*, **64**, 807, 1924). The handling system, drying processes, kilns, etc. are described and fully illustrated. The plant has an annual output of 50,000 tons of clay ware, mainly sewer pipes, terra cotta, roofing tiles, face bricks, drain and hollow tiles. There are 22 down-draught kilns, 10 muffle kilns, and a recently installed tunnel kiln of the Russell type.

THE SAND-LIME BRICK PROCESS.—(*J. Soc. Chem. Ind.*, **43**, 508, 1924). The process consists essentially in mixing sand with 5-10% of slaked lime, forming this into a secondary mass with water, passing it into a brick-moulding machine operating at a pressure of 2 tons per sq. in., and then exposing for 10 hours in closed cylinders to steam pressure of about 120 lb. per sq. in., *i.e.*, a temp. of approx. 350°F. The main considerations are: (1) that the lime should contain no trace of unslaked lime (CaO), and (2), that there must be a thorough mixing. The whole process can be completed in 24-36 hours. The main advantages of sand-lime bricks are: (1) Strength (mechanical crushing strain 5,132 lb. per sq. in.) ; (2) less absorbent to water than ordinary bricks ; (3) they can all be used as "facing" bricks, being straight and of equal size.

MODERN GRINDING METHODS IN CALIFORNIA.—J. W. Wright and G. R. Boggs (*Cer. Ind.*, **2**, 207, 1924). The plant of the American Grinding Co., at Los Angeles is described. The raw materials are conveyed to a chrome-steel jaw crusher, which will crush clay, flint, and spar alternately as required. The crushed material, in pieces three-quarters of an inch in diameter and smaller, is elevated to 100-ton bins, from which it is fed continuously with a constant volume of water, into a Hardinge mill, measuring 8 ft. by 22 in. The fines produced in this mill are carried out with the overflow, and are then pumped into a small hydro-separator (Dorr Thickener).

In the latter, the grain-size of the finished product is determined by the degree of dilution of the thickener contents. The separation of flint or spar to pass a 200-mesh sieve requires a dilution of about 18 parts of water to one of solid matter, and for clay to pass a 300-mesh the rate would be 25 water to one of clay. The fines from this separator are carried away in the overflow, by way of a magnetic separator, into a second and larger Dorr Thickener, the mechanism of which is installed in a cylindrical tank measuring 54 ft. diameter and 14 ft. deep. Here the solid particles settle very slowly, undergoing meanwhile a sort of blunging action, which seems to add to the plasticity of the finished product. It is estimated that the solid matter remains in this thickener for an average period of 48 hours. The settling particles, however, are not allowed to form a solid mass at the bottom, but are drawn off in semi-fluid form and pumped directly to a Sweetland continuous filter. The overflow from this second separation process is relatively clear water and is filtered through barium cake to precipitate any sulphates dissolved from the raw materials. It is then returned to the primary reservoir and used over again.

The coarser material, which settles to the bottom of the first Dorr thickener, is drawn off continuously. Among the larger particles of this coarse material many smaller particles are imprisoned, and in order to avoid the loss of these valuable fines, all the settlings are pumped into a Dorr Bowl Classifier. Here, by means of a special dilution procedure, the larger particles are segregated in the lower portion of the bowl, and again drawn off. These final settlings, containing the coarsest portions of the original ground material, are then returned to the Hardinge mill to go through the same cycle of operations again. The fines extracted in the bowl classifier are carried away in the overflow, passed over the magnetic separator, and finally reach the second Dorr thickener described above.

Filtering.—The semi-fluid settlings from the second thickener are pumped directly to a continuous American filter. This apparatus consists of 12 discs mounted on a hollow shaft, through which either suction or air pressure can be applied to the disc. Each disc is divided into nine V-shaped sections, or sectors, which are covered with heavy canvas duck. The discs revolve slowly through a trough into which the slip has been pumped. While the sectors are passing through the slip, suction is applied automatically, and this suction continues for awhile, even after the sector has left the slip, in order to bring about rapid drying. At a definite point in the revolution, before the sector re-enters the slip, suction is automatically cut off, and air under pressure enters the section, thus inflating it. The inflated sector engages wooden scrapers, which remove the caked substance from both its sides. This material falls into large cars beneath the floor. *Drying.*—When filled, these cars move forward into a humidity dryer of the tunnel type. A temperature not exceeding 250°F. within the dryer promotes rapid drying.

TERRA SIGILLATA.—Steger (*Sprech.*, **57**, 285, 1924). Several methods of making terra sigillata (better-Samian ware) are described. According to C. and G. Fischer (German Pat. No. 206,395), the desired effect can be obtained by applying an engobe in the usual way to clay ware in a semi-dry, dry, or semi-fired condition. The ware is then allowed to dry, after which the surface is thoroughly polished. In the subsequent, final firing the engobe is thoroughly burned on without, however, losing its polished surface.

Other investigators have attempted to fathom the mystery of the sigillata by searching for a suitable mixture for the engobe. According to F. Lossen (German Pat. No. 261,500), the coating is prepared in a simple way by thoroughly mixing a finely-ground fat, red-burning clay containing iron with a suitable quantity of fine pumice stone, with, or without, the addition of alkalis, such as potash solution. This engobe is applied in the ordinary way to the dried, or partially fired ware, which is then fired to 1,000°C. The final glaze then consists of a fused mass of pumice, in which the small, red particles of clay are embedded, giving the ware the well-known reddish-brown,

velvety gloss of the antiques. Dr. Heinecke, a former Director of the State Porcelain Works, Berlin, proceeds in a similar manner (German Pat. No. 339,339). A flux and a clay containing at least 10% of finely-divided iron oxide, together with a certain amount of organic matter (carbo-hydrates), are thoroughly mixed together. This mixture is then applied in a thin coat to the fired or unfired ware, which is thereupon placed in a suitable kiln and fired in a reducing atmosphere. The red colour is produced by the reduction of the iron oxide, probably to metallic iron, brought about by the action at a temperature of about 400° of the carbon released by the decomposition of the carbohydrates at the commencement of the firing. A temperature of 800°C. should not be exceeded, and reducing conditions must be maintained throughout so as to prevent re-oxidation of the reduced iron. During the cooling period, air is admitted so that the temperature is allowed to fall slowly. The iron contained in the glaze is then converted into the brilliant red oxide. The kiln should be of such a type as to admit the flame to the ware, the latter, however, being protected from ashes and flue-dust. On a small scale, a muffle with a perforated bottom might be used. Beneath this perforated sole, another plate, also perforated, is placed, at a suitable distance, in such a manner that the perforations are not in line with those of the muffle bottom. In ancient times the making of terra sigillata was taken up wherever a suitable red clay was to be found. From this clay a body was obtained by washing, which served as the engobe. The glaze was applied to the dried ware by dipping in a suitable slip. This is clearly demonstrated by finger marks round the base of many pieces of ancient ware. The ruins of ancient kilns show unmistakeably that the firing chamber and the combustion chamber were quite separate. The kilns were fired with beech wood, as is proved by the charcoal remains. The alkalis from the wood fuel were carried along with the hot gases and settled on the ware, imparting to the engobe a glaze-like appearance. A vase now in the Berlin Old Museum inducates beyond doubt that the glossy surface of the ware was produced by the action of the alkalis in the flue gases. The body of this piece consists of three distinct layers, the body proper, the red engobe, and the glossy surface. The latter has chipped off in places, exposing the red engobe, indicating that the temperature in the kiln had not been sufficiently high to effect a complete fusion between the layers. Nowadays this type of ware would have to be fired in muffles or saggars, and the necessary alkalis would have to be added in a suitable form to the engobe. In order to obtain the beautiful red colour, the firing, particularly in the final stages, would have to be carried out in an oxidising atmosphere, to bring about the formation of iron oxide.

Patents

PATENT REFRACTORY MATERIALS.—J. Harter and A. U. Kohler (*Brit. Pats.*, 216,514-519, May, 1924). Substances containing silica and alumina, such as mixtures of bauxite and kaolin, are heated to a temperature of at least 90 per cent. of the temperature of fusion, the mixture being preferably first moulded into blocks with the optional addition of a temporary binder. It is then crushed, mixed with a refractory binding agent—preferably a portion of the raw material—moulded, dried, and fired again to the previous temperature or to a lower temperature. A similar procedure is adopted in the manufacture of refractories of clay or kaolin. In this case, the final firing temperature should be 3,000-3,250°F , and the binder should consist of unburnt kaolin, which should constitute 25 per cent. of the product.

MAKING AND WATER-PROOFING BRICKS, PIPES, POTTERY, ETC.—J. U. Ahlmann-Ohlsen (*Pat. J.*, 185, 1924). No. 218,127. July 25, 1923. A mixture of diatomaceous earth, clay, and a low-fusing flux (alkali silicate) is moulded, baked, and finally impregnated with melted asphalt, tar, pitch, bitumen or paraffin. Example I.—5 parts dried and ground diatom. earth, 1 part clay, and 1 part flux such as mineral meal, are moulded

wet, dried, and fired to 1,400-1,800°F., and while still hot are dipped into asphalt or like material. Example II.—10 parts raw. dried diatom. earth, 5 parts burned diatom. earth, 4 parts clay, 1 part alkali silicate. The products are acid-proof and impermeable to air and fluids.

COMPOUNDING AND PREPARATION OF BODIES, ETC.

USE OF BERYL IN PORCELAIN MANUFACTURE.—(*Chem. Age*, **11**, 193, 1924) Investigations by the U.S. Bureau of Standards have shown that when beryl is substituted in amounts varying from 28 to 45 per cent. for felspar in porcelain bodies, the other compounds being silica and clays, a product is obtained which displays a very high electrical resistance, and a low thermal expansion. This porcelain is, therefore, considered a very promising material for electrical purposes, but, owing to the scarcity of beryl, there has been no production of this type of porcelain on a commercial scale.

PATENTS

IMPROVEMENTS IN, OR RELATING TO THE MANUFACTURE OF FIRE-PROOF BRICKS.—S. E. Sieurin, *Brit. Pat. No.* 218, 495, July 17, 1923. The under-load refractoriness of grog bricks is considerably increased by the addition to the coarse-grained material of a finely-divided binding mass consisting of an intimate mixture of SiO_2 material and fire clay. The mixture must be such that, after heating to glowing heat, it contains 73-90% SiO_2.

IMPROVEMENTS IN THE MANUFACTURE OF BASIC BRICKS, FURNACE LININGS, RETORTS AND THE LIKE.—H. Hodson, *Brit. Pat. No.* 218,720, Jan. 7, 1924. Additional to Spec. 211, 944. The plastic mass described therein is first allowed to cool, then ground and, after moistening, moulded into bricks, etc., and finally burnt.

SHAPING, MOULDING, DRYING, ETC.

WASTE HEAT DRYERS FOR WHITE WARE.—T. C. Walker (*J. Amer. Cer. Soc.*, **7**, 630, 1924). In most dryers the circulation of air is from end to end. The hot air is generally fed in at the bottom of the drawing end, and takes up enough moisture to acquire relatively high humidity, thus drying the ware very slowly at the charging end. But the humidity cannot be controlled.

In a dryer which has recently been designed by the Los Angeles Pressed Brick Co., to dry ten tons of filter-pressed cake in twenty-four hours, the air enters at the side near the top through inlets spaced four feet apart, each having a blast gate. As the hot air enters the dryer, it has a cyclonic effect, circulating through every part of the tunnel, even to the corners. The blast gates at each inlet allow the flow of air to be changed in the different parts of the dryer, so that the clay at the drawing end, or elsewhere, may be dried more quickly if required. The tunnel is 33 feet long, 8 ft. 6 in. wide and 6 ft. high, and has a lift roller door at each end. The walls are constructed of 4-inch hollow tiles, resting on a concrete floor. The top is of reinforced concrete, 4 inches thick, but hollow tiles may also be used here, if properly reinforced. On one side of the dryer, a sheet iron box covering six steam coils is arranged. From this box two sheet-iron ducts, 18 inches square, run along the side of the dryer. Openings measuring 3 in. by 12 in., spaced 4 feet apart, lead into the tunnel near the top. In the opposite side, near the bottom, are similar ducts measuring 6 in. by 12 in. At the top is the exhaust stack, fitted with a blast gate, and at the bottom is the return duct, of 18-in. sewer pipe, also fitted with a blast gate. This gives complete circulation of the drying air through the fan, dryer, and back to the fan, or the drier air may be exhausted through the blast gate and the exhaust stack. The fan produces a change of air four to six times per minute, and the heat may be obtained either from the kilns or from the steam coils, or both. A dryer of

this type operates most efficiently between the temperatures 190° and 200°F. A hygrometer is fixed inside the tunnel near the centre, and the humidity is controlled by proper manipulation of the blast gates. One or more of the steam coils can be brought into operation to maintain the required temperature as the cooling kilns become spent of their effective waste heat. The temperature should never fall below 180°F. and the humidity should not exceed 30 per cent. The dryer requires very little attention.

ON FILTERING POTTERY SLIPS.—L. Hertenbein (*Cer.*, **27**, 77, 1924). A short account is given of the various mechanical methods, which have been employed from time to time, to effect the consolidation of pottery slips without resorting to the primitive system of decantation. A new machine is then described in some detail. It is of the rotary type, its chief advantage being continuity in operation ; while constant permeability of the filter cloths is maintained without the risk of damage to the cloths, which would result from scraping or brushing. The Hertenbein Rotary Filter consists of a drum, which is formed of a series of separate and interchangeable boxes or compartments placed in the framework. Each of these boxes is air-tight on all sides, with the exception of the circumferential, *i.e.*, the curved, portion. This is covered with a cloth, or other suitable perforated material, over which the filter cloth is fixed. In line with the drum and in contact with it, is a solid (cast) cylinder, which revolves at the same peripheral speed as the drum, but in opposite direction. This is the cleaning cylinder. Each box is connected by a series of tubes to the suction and pressure distributors. The drum revolves within a tank which contains the slip, the drum being almost submerged within the liquid. As the drum revolves, each box in turn becomes submerged, and at that moment suction is induced in the box. The liquid is drawn through the filter cloths, leaving a thin layer of solid matter on the outside. This layer increases in thickness during the passage of the box through the liquid, and, since suction continues for a short time after the box emerges, the solid layer is dried and hardened to a certain extent. At the moment when the box reaches the cleaning cylinder, suction ceases, and a slight pressure (30 to 50 gr.) is automatically induced within the box. This has the effect of lightly raising the solid layer, which then adheres to the cleaning cylinder, from which it is removed by means of a scraper. The cloths are freed entirely of filtered matter by the air under pressure, and thus regain their original filtering capacity with each revolution of the drum ; and since no brushing or scraping is required, they are subjected to very little wear and tear.

Patents

MOULDING CLAY.—Roth Akt. Ges.(*Pat. J.*, 1,849, 1924). No. 215,207. Feb. 27, 1923. The patent relates to the treatment of pulverised clay or dust for moulding, and consists in providing the granules with a superficially dried outer layer to prevent adhesion to the moulds. The machine is described.

TEAPOT SHAPES.—B. Cliff (*Pat J.*, 1,855, 1924). No. 217,473, Aug. 29, 1923. Refers to teapots of hexagonal or other polygonal shape. The spout is so formed that one longitudinal half lies within the contour of the sides of the pot, and the other half lies outside. The spout has a bevelled lip. The handle and the lid are formed so as to facilitate stacking of the pots.

CASTING PLASTER MOULDS.—J. H., J. A. and J. S. Jackson, and J. H. Jones (*Pat. J.*, 1,857, 1924). No. 217,966, Mar. 17, 1923. Apparatus for casting plaster moulds is described. It comprises a pair of open-ended, annular elements adapted to interengage by a rabbeted connection, from which the formed mould may be removed by separation of the parts.

TEAPOT SPOUTS.—D. Barlow (*Pat. J.*, 1,858, 1924). No. 218,509, July 31, 1923. The spout, which is short, is formed without a grid, sieve or straining holes, and is arranged at the top of the vessel with the pouring lip on a level with the underside of the flange surrounding the mouth opening.

EARTHENWARE DRAIN PIPES.—F. G. Shearley (*Brit. Pat.* 219,485, 20 July, 1923). A junction is described which is of telescopic form in two parts, to be used to replace broken pipes or to form junctions in an existing pipe line.

KILNS, OVENS, MUFFLES; FIRING TECHNIQUE, ETC.

DETERMINATION OF THE "DEW POINT" OF GASES IN CONTINUOUS CERAMIC KILNS.—P. de Groote (*Cer. et Verr.*, **44**, 301, 1924). A method of calculating the temperature point below which water-vapour, contained in gases of combustion in Hoffmann and tunnel kilns, begins to condense on the ware, is outlined. Diagrams are reproduced, by the aid of which this temperature can be read off, with sufficient accuracy for practical purposes, given the following data: (1) Total water content of the goods; (2) The percentage of ash in the fuel employed; (3) the CO_2-content of the gases; (4) the amount of fuel consumed per 100 kg. of ware.

THE OXIDATION OF CERAMIC WARES DURING FIRING, V.—A QUANTITATIVE STUDY OF THE NATURE OF SULPHUR EVOLUTION IN KILN-FIRING, (PART I.)—F. G. Jackson (*J. Amer. Cer. Soc.* **7**, 634, 1924). Reference is made to the author's previous papers (*Ibid*, **7**, 223 and 427, 1924) giving the results of laboratory work. Similar investigations, carried out subsequently under industrial conditions, are then recorded. Four industrial brick kilns were studied. Curves are given, showing the amount of sulphur entering and leaving the kilns, and also the kiln content of sulphur. The gas samples were taken through fused silica tubes placed in suitable positions in the stacks. At one of the plants, where the sulphur problem was serious, an attempt was made to strike a "sulphur balance":—

	Weight (lbs.)	Per cent. of fired bricks
Sulphur set in kiln in ware	1230	0·359
Sulphur entering kiln in gases	1693	0·494
Total sulphur entering kiln	2923	0·853
Sulphur leaving kiln in flue gas	2965	0·865
Difference (experimental error)	42	0·012

From these and other data, it was possible to obtain a running record of the amount of sulphur in the kiln at all times. Draw trials were made at frequent intervals and were analysed for sulphur, both on the surface and in the centre. The method of analysis is described and the results are tabulated. The latter show the percentage of soluble sulphur (in water and in aqua regia), both in the outer skin and in the heart of draw trials taken at numerous intervals throughout the firing.

NOTES ON THE BEHAVIOUR OF REFRACTORIES IN GLASS MELTING FURNACES.—H. Insley (*J. Amer. Cer. Soc.*, **7**, 583, 1924). The paper gives the results of macroscopic and microscopic examination of refractories after service in a soda-lime glass melting furnace, seven photomicrographs being reproduced in support of the conclusions drawn regarding causes of failure, etc. With regard to the solvent action of soda-lime glass on clay refractories below the glass line, the author corrects an opinion expressed in a previous paper, viz., that the layer of corundum crystals formed adjacent to the contact zone, but within the glass, is caused by the loss of water and recrystallation of gibbsite, $Al(OH)_3$ or diaspore, $AlO(OH)$ in the refractory. As the result of further study, he now holds that these crystals of corundum are formed by the action of glass on clay refractories containing no aluminium hydroxides originally. As the aluminium silicates dissolve

in the molten glass, the concentration of alumina in the contact zone increases to the point of super-saturation, and corundum is deposited. Since, therefore, corundum is less soluble in molten soda-lime glass than the aluminium silicates in the clays, it is concluded that high alumina refractories would be more resistant to the solvent action of the glass than fireclay refractories. The refractories above the glass line are subject to the action of sodium compounds in the furnace gases. In this case also it is shown that the clay refractories are less resistant than the silica. Furthermore, it is pointed out that refractories containing a much higher percentage of alumina than silica should resist the fluxing action of soda better than the usual clay refractories. Stress is laid on the need of a suitable refractory mortar for the areas where clay and silica refractories are in contact and exposed to the action of soda in the glass furnace atmosphere. This mortar would have to be of such a nature as not to combine either with the soda, alumina and silica on the clay side, or with the soda and silica on the silica side to form compounds with melting points below the temperature of the furnace.

ON TESTING FLUE GASES.—F. A. Buchholz (*Deut. Töp. Zieg. Ztg.*, **55**, 93, 1924). The CO_2 content of the flue gases gives an indication of the amount of excess air being employed. In measuring the CO_2-content of a gas electrically, advantage is taken of the fact that its thermal conductivity is much lower than that of nitrogen, oxygen, or carbon monoxide. If two platinum wires of equal thickness are passed through the centres of two narrow, metallic tubes filled with air and an electric current is passed through them, they will both reach the same temperature. If, however, CO_2 is added to the air in one of the tubes, the temperature of the wire passing through it will rise, because the CO_2 conducts the heat from the wire to the walls of the tube less readily than air. The difference in the temperature of the two wires is then a measure of the CO_2 content in the one tube. This difference in temperature can be measured electrically, since the resistance offered by a wire to the passage of an electric current varies with the temperature. This is the principle of the Siemens and Halske CO_2 Meter. The flue gases can be tested electrically for unburned gases (CO and hydrogen) also. This is done by subsequently igniting these gases and measuring the resulting rise in temperature, from which the volume of inflammable gases present can be calculated. For this purpose, it is not necessary to heat the gases up to their ignition temperatures. If certain substances, *e.g.*, platinum, are present, combustion will take place at a much lower temperature. This so-called catalytic combustion is utilised by the above-mentioned firm in their apparatus for the determination of inflammable gases in flue gases ; and this apparatus can be used in conjunction with the CO_2 meter, in which case it should be the object of the fireman to maintain the CO pointer at zero and the CO_2 recorder at as high a figure as possible.

Patents

MUFFLE FURNACE.—F. J. Tone (*U.S.Pat.*, 1,502,070, 22 July, 1924). A muffle flue for furnaces is composed on three sides, which form part of the chamber wall, of a material of relatively high thermal conductivity (clay tile), and on the heat-radiating side of a material of relatively low thermal conductivity (silicon carbide).

TUNNEL KILN.—H. Koppers (*Ger. Pat.* 391,662, 8 June, 1922). By means of ordinary dampers, acting as baffles, the kiln gases are directed downward in the pre-heating zone and upward in the cooling zone. In a dual arrangement of tunnels, the cooling zones are connected by apertures near the hot zone with the neighbouring pre-heating zones. Uniform distribution of temperature is thus attained.

FURNACE-LINING BRICKS.—C. F. Priest (*Pat. J.*, 1,854, 1924). No. 217,160, Feb. 2, 1923. Interlocking bricks are described, having interfitting projections and recesses on two opposite faces. The bricks are so formed,

that the corners are of full thickness. The arrangement is such, that when the bricks are laid to break joint, relative movement in either direction between adjacent courses is prevented.

CHARGING SHAFT KILNS.—P. Dumont (*Pal. J.*, 1,857, 1924). No. 217,970, Mar. 20, 1923. By means of the arrangement described, the charging is so effected, that the finer portions of the charge collect in an annular column between a central cone and an outer column of the coarser portions.

SAGGARS.—J. E. Tams and W. H. Edwards (*Pat. J.*, 1,857, 1924). No. 218,084, June 9, 1923. A support for pottery during firing consists of a metal base with sockets, into which are fitted three vertical clay, fireclay or similar rods having integral knife-edge projections. The tops of the rods may be connected by a similar plate.

TWIN-TUNNEL KILN AND METHOD OF OPERATING THE SAME.—C. Dressler, (*U.S. Pat. No.* 499, 354, July 1, 1924.) Forced circulation of the kiln atmosphere is set up in the end portion of a twin-tunnel kiln along paths looped about the kiln axis, the object being to provide a method of regulating the rate of heat transfer from the hotter to the colder ware.

CHARGING FUEL TO BRICK KILNS.—J. Gairing (*Brit. Pat.*, 218,881, 5 September, 1923). The fuel is fed into the kiln from a receptacle having at its lower end a rotary disc, which is carried on a shaft supported in bearings. The disc is provided on its underside with a vertical wall, S-shaped in plan, and a plate of screw form. The device may be adapted for continuous feeding by rotating the disc from above and forming the plate so that it connects with an outlet arranged in the centre of the casing.

GLAZES, ENAMELS.

ENAMELLING PLANT WITH A NEW TYPE OF DUST COLLECTING SYSTEM.—(*Cer. Ind.*, **2**, 279, 1924). A well-illustrated account is given of the plant, machinery, methods, etc., employed by the Roberts and Manders Stove Co., at Hatboro, Pa. The dust-collecting system is said to be particularly efficient. In the brushing department, for instance, the top of the table is covered with a slotted metal surface, through which the dust is drawn by suction.

THE EFFECT OF ZIRCONIA IN ENAMELS FOR SHEET STEEL.—H. G. Wolfram (*J. Amer. Cer. Soc.*, **7**, 1, 1924). The effect of additions of zirconia to enamels for sheet iron and steel is studied. Additions of zirconia to the smelter batch increased the time of smelting. They also make the enamel more viscous, and thus increase the time of burning. Increasing additions to the ground coat smelter batch increased the resistance to impact. Highest resistance was obtained by increasing additions to the cover coat smelter batch; but increased resistance was also attained by substituting zirconia for tin oxide in the mill. Zirconia enamels showed higher resistance to thermal shock than tin enamels, but increasing amounts of Z. in the smelter batch lowers the resistance. Resistance to acids was not increased by additions to the smelter batch, but a slight increase was obtained by substituting for tin oxide in the mill.

PREPARATION OF ENAMELS AND CERAMIC GLAZES AND OF A FELSPAR SUBSTITUTE FOR CERAMIC BODIES.—Ges. für Tuff-und Ton-Technik m.b. H. (*Ger. Pat.* 395,824, 11 Nov., 1921). Suitable raw materials, *e.g.*, igneous rocks, artificial slags, etc., are decomposed by treatment with alkalis or other chemical reagents (if necessary, with the addition of organic colloids), under high temperature and pressure. The raw materials may be subjected to a preliminary mechanical disintegration. The process aims at the elimination of the grinding operation.

GLAZES FOR REFRACTORY BRICKS, ETC.—D. Thornton and E. S. Illingworth (*Pat. J.*, 1,855, 1924). No. 217,377, Apr. 16, 1923. Refractories

are rendered resistant to acids and salts by dipping them while plastic in a solution of a vitreous enamel or glaze consisting of seven parts Cornish stone, 4 parts felspar, one part whitening, one part flint, and one part plaster of Paris. The subsequent treatment is the same as in making white or coloured glazed bricks.

ZIRCONIA AS A FLUX AT HIGH TEMPERATURES.—H. H. Stephenson (*Can. Chem. Met.*, **8**, 131, 1924). Zirconia is generally regarded as an opacifier, but at high temperatures, it acts as a flux, producing glossy enamels of lustre and brilliancy comparable to those of lead at lower temperatures. High-fire glazes are alumino-silicates of lime, barium and magnesia. Though pleasant in appearance, they give a somewhat hard impression, and they do not exhibit the brilliancy and refractive index of lead glazes. The addition of a small percentage of zirconia will impart the desirable lustre to any glaze above cone 10.

MICROSCOPIC DETECTION OF SMOKED EARTHENWARE GLAZES.—A. Schoblik (*Ker. Rund.*, **32**, 498, 1924). Many blistered or matt glazes can scarcely be distinguished from each other by their appearance; consequently, the cause of the fault is often extremely difficult to determine. With the aid of the microscope it is possible to determine the characteristic feaitures of the various faults, and thus diagnose the trouble easily and correctly. This method of testing is of particular value to the kiln foreman, since it frequently gives him the possibility of saving a kiln when the draw trials indicate a crazed or smoked glaze. The faults produced by the action of kiln gases on earthenware glazes may be divided into three groups: (1) Glazes with inclusions of carbon compounds in a gaseous form; 2. Glazes which have simply been reduced (metal deposits); 3. Glazes with inclusions of carbon. Either group 2 or group 3 always occurs in conjunction with the first, but it is also possible to have all three together. If incomplete combustion of the fuel is taking place, not only carbon dioxide, sulphur dioxide and water vapour are formed, but carbon monoxide, methane, ethane, and other hydrocarbons and hydrogen sulphides are also given off. This not only implies a waste of fuel, but it is also very detrimental to the glaze. Even a small volume of carbon monoxide is sufficient to cause blisters; the carbon gases combined with the water vapour, which is always present in the kiln gases, become imprisoned in the glaze before the melting point is reached and are unable to escape at higher temperatures on account of the viscosity of the glaze. Reduced glazes are the result of greater reaction with reducing gases; the lead oxide of the glaze is reduced to metallic lead. These glazes are grey in appearance and are permeated with innumerable gas bubbles, which contain kiln gases. The effect of the heavy hydrocarbons is to produce a deposition of carbon, in addition to the formation of gas bubbles and metallic lead. Re-oxidation of the carbon and lead can only be effected by bringing them to the surface of the glaze and submitting them to the action of a highly oxidising kiln atmosphere. The preparation of thin sections for the microscope is not particularly difficult; nevertheless it requires some experience with special apparatus.

1. *Glazes having inclusions of gaseous carbon compounds* are more or less of a blistered character. The number and size of the bubbles is dependent upon the duration and strength of the carbon gases. In its least severe form, the glaze is found to contain microscopic bubbles; neither the appearance nor the quality of the glaze is seriously affected. Glazes rich in lead, however, are slightly discoloured. If the glaze is not very viscous, the bubbles burst, forming a prickly surface. A photomicrograph of such a glaze shows that the number and size of the blisters is very small. A more severe type of smoking shows blister formation on a larger scale. The appearance of the glaze has suffered severely, whilst the surface is very uneven and has lost its gloss. Gas bubbles are also seen to have risen to the surface in large numbers. The thin film of glaze covering these bubbles and also in the vicinity of the blisters (burst bubbles), is seen under the microscope to contain crystal formations

of various forms. This crystallisation is present in all badly smoked glazes, but it becomes particularly apparent when the "smoking" occurs near the end of the firing. In bad cases of smoking, the bubbles grow to the size of several millimetres in diameter, and, in most instances, they burst, leaving what may be termed glaze rings. The microscope shows that these rings sometimes contain innumerable smaller bubbles, which have formed round the edge of the original bubble. This indicates the inclusion of gaseous carbon compounds only, but in some cases, the rings show evidence of the reduction of lead compounds also.

2. *Reduced glazes, with metal deposits.* These glazes often have a grey or black appearance, and the ware is usually considered as waste. However, it is possible, by firing a second time in a strongly oxidising atmosphere, to render such ware saleable. Microscopical examination of a glaze, which had been exposed to the action of reducing gases in the first stages of the firing, gave no evidence of reduction and bubble formation on the surface of the glaze; but the lower layer was found to be full of bubbles surrounded by deposited lead. The injurious gases which, in the initial stages of the firing had penetrated into the soft glaze, had become imprisoned when the kiln reached a higher temperature; and the subsequent oxidising burn had only succeeded in releasing them from the upper layer.

Owing to faulty kiln construction, insufficient draught, or incorrect methods of firing, it frequently happens that the kiln atmosphere is of a strongly reducing nature throughout the firing period. Under the microscope, a glaze fired under such conditions shows innumerable large and small bubbles, surrounded by deposits of lead and carbon, distributed throughout the ware. If, as frequently happens, the kiln is forced toward the end of a burn, strongly reducing conditions are produced in the kiln, causing smoked ware. A badly smoked glaze produced in this way has the appearance, when examined microscopically, of a black matt glaze. Among the mass of dark bubbles, a few light specks can be seen. The latter are caused by burst bubbles, through which the lower, unsmoked layer of glaze becomes visible. Under powerful magnification, a single bubble appears lighter in the centre and crowded with crystals of various forms. In the outer part, there are large numbers of tiny closely packed bubbles, with carbon inclusions. On examining a section through this glaze it was seen that only a thin surface layer had been affected. The ware was, therefore, again subjected to a normal glost fire, with the result that the lead and carbon inclusions were entirely eliminated, and only a few small bubbles, such as are present in every glaze, were visible.

3. *Glazes with inclusions of carbon only.* This type only occurs with leadless glazes, since in lead glazes, deposition of carbon is always preceded by the reduction of the lead compounds. If a leadless glaze and a lead glaze are placed together in a kiln and fired in a slightly reducing atmosphere, the former will come out somewhat blistered but of a good colour, whilst the latter will be grey in colour, due to metallic lead. In a more strongly reducing fire, the leadless glaze will also be discoloured owing to deposited carbon. The photomicrograph of such a glaze exhibits large and small blisters together with deposited carbon and crystal formation. To what extent reducing conditions have prevailed during the firing can be judged by the distribution of the gas bubbles in the glaze.

COLOURS, DECORATIVE PROCESSES, ETC.

GALVANISING POTTERY AND GLASS WARE.—(*Diamant*, **46**, 250, 1924). Copper or silver galvanoplastic decorations in relief may be applied with pleasing effect to bowls, tea or coffee services, glasses, etc. For this purpose the ordinary processes for applying the conductive metallic film cannot be relied upon, since the raised portions of the design must be firmly attached. The design, flowers, monograms, etc., should be painted on in liquid gold, silver, or platinum, the piece then allowed to dry, and fired in a muffle to a dull red heat. This gives a bright, metallic film, which is fused on to the

glaze, and which is then ready to be coppered or silvered. The design can be attached even more firmly by thoroughly mixing silver enamel and lard oil on a glass or a porcelain plate, applying this to the ware with a brush and firing on in a muffle. In addition to silver, the enamel also contains fluxes, which produce a firm union between the silver and the ware. After firing on, the design is cleaned with a fine copper brush and the piece placed in the galvanising bath, the current being directed to the metallic portions by means of fine copper wires.

A SYSTEM FOR HARMONISING COLOURS.—(*Chem. Age,* **8,** 620, 1923). The Taylor System is described. There are 3 illustrations of the method.

COPPER REDS FOR THE AMATEUR.—P. E. Cox (*J. Amer. Cer. Soc.,* **6,** 685, 1923). A brief review is given of the history of the production of copper red effects. Methods are then described to enable the process to be applied by a person having a china painter's kiln. The object of the paper is to encourage the amateur to make use of simple equipment for the production of this type of decorated ware.

PLANT AND MACHINERY, ETC.

PRACTICAL DISSERTATION ON PEBBLE MILLS.—E. W. Lawler (*Cer. Ind.,* **2,** 369, 1924). The grinding mill is often a source of contamination of potters' materials with iron, and this, in the case of the pebble or ball mill, is largely due to defective man-holes. This trouble could be avoided if, instead of lining the cover with porcelain or silex, a block of rubber were attached to the cover. The whole mill could with advantage, be lined with rubber. The cost of lining a 6×8-ft. mill with silex, including material and labour, would amount to £60 or £80, and the internal diameter would be reduced by 6 inches.

A $\frac{5}{8}$-inch rubber lining has been installed in a mill loaded with iron balls and grinding ore in a mining plant and has been run continuously for three months at 24 hours per day. After grinding at least 1,000 tons, it was found that the lining of the mill showed no signs of wear whatever. It is still running after 9 months. It is claimed that rubber lining in a ball mill increases the capacity and reduces the cost of grinding. The type of pebble to be used in the mill is also discussed. The more pebbles in the mill, the greater the grinding capacity, and the shape of the pebbles determines their efficiency. With round pebbles, the voids are greater than with irregular-shaped pebbles, and to increase the grinding the voids should be reduced. The correct size of pebble should be put in from the first. The charge must also be correct for the size of the mill and the pebbles. The latter fill about half the mill and the charge, in dry measure, about 23%. The water in wet grinding is additional. The quantity of water should be kept as low as possible. If the slip is too thin, the pebbles break, the lining wears, and the time of grinding is increased. If, on the other hand, it is too thick, power is consumed and no grinding is done.

DRESSING BURNED REFRACTORIES.—(*Brick,* **64,** 724, 1924; *Cer. Ind.,* **2,** 294, 1924). A dressing machine is described which combines the reciprocating platform motion of a planer with the rotary, even cutting action of a milling machine and the rotary speed of a disc grinder. The cutting action is produced by 120 gear-like tool-steel cutters, about one inch in diameter, each of which is mounted on a separate small shaft in the disc, each cutter being free to rotate on its own shaft. As the disc rotates, each cutter removes a small amount of burned clay. Since each of the 120 cutters is free to rotate on its own shaft, the milling or dressing action is very gentle, and does not tend to disrupt, tear, or crack the block, nor to overheat it through excessive friction. The progressive action of the machine is similar to that of the continuous milling cutter, which has, for instance, three cutters, each removing $\frac{1}{16}$in. of metal in a single operation to give a total cut of $\frac{3}{16}$in. The whole cutting disc is composed of a central disc, with its row of small

gear-like cutters, and a series of hoop-like concentric cutters, each of which is adapted to fit over a previous hoop to give a greater grinding capacity when large blocks are being treated. The machine at present in use has a central disc and five concentric hoops. For a future installation, however, the inventor, W. G. Bergman, has planned an eight-part disc with staggered cutters. It is claimed that this process could be applied on a commercial scale to the regular run of nine-inch and blast furnace bricks. This would mean a slightly higher cost than the sizing of green bricks, but it would provide an opportunity to size the bricks to any desired dimensions, and would eliminate the small variations in size which occur in burning. As the bricks were unloaded from the kiln, they could be run on a small conveyor between two rotating discs or past one such disc and carried straight forward to the stock shed.

PATENTS

BRICK-MAKING MACHINE.—R. Zondervan and J. Stoederum (*Pat. J.*, 1,835, 1924). No. 210,339, May 10, 1923. Relates to stationary-mould machines, in which the moulds have movable bottoms, which are raised by a piston to compress the material against a hinged lid.

MOULDING ELECTRIC INSULATORS.—J. Roth Akt. Ges. (*Pat. J.*, 1,836, 1924). No. 210,689, May 29, 1923. Relates to stationary mould machines, pressing plungers and dies, delivery, and feeding.

BRICK PRESSES.—R. Navet (*Pat. J.*, 1,839, 1924). Nos. 211,502/4, Feb. 15, 1924. The patents relate to modifications in the pressure lever.

MOULDING TILES.—C. Terry (*Pat. J.*, 1,848, 1924). No. 214,791, Mar. 12, 1923. Description of a machine, in which the core is adapted to be moved into and out of the mould box.

III.—FINISHED PRODUCTS: TESTING, ETC.

CARBORUNDUM RETORTS.—M. Barrett (*Gas World*, **80**, 588, 1924). The principal property of carborundum which renders it superior to fireclay or silica is its high thermal conductivity, which, in the bonded form, is seven times that of the other two materials. In addition, carborundum walls may be thinner than is usual with other materials, and it is now common practice to form hollow panels in carborundum shapes. A sectional, panelled retort is illustrated. The panel treatment is necessary in order that good, substantial joints may be made.

STUDIES ON THE THERMAL CONDUCTIVITIES OF SOME REFRACTORY MATERIALS.—O. S. Buckner (*J. Amer. Cer. Soc.*, **7**, 19, 1924). The paper gives the result of work undertaken for the purpose of obtaining reliable conductivity coefficients on several types of refractory bricks made from ceramic bonded electric furnace products. The method employed was a modification of that suggested by Hepplewhite, alterations being made for the purpose of ensuring greater accuracy. Care was taken to prevent diffusion of furnace gases into the test piece by protection of the lower surface with a dense refractory plate. An additional air calorimeter or guard ring was placed around the calorimeter on which measurements were taken in order to maintain the entire upper surface at an even temperature. The coefficients of thermal conductivity for the various materials studied (in c.g.s. units) were: silica bricks 0·00099; fireclay bricks 0·00169; fireclay slab 0·00203; light weight fireclay bricks 0·00251; sillimanite bricks 0·00432; electrically sintered magnesia bricks, 0·00655; "Alundum" firebricks 0·00833; "Crystolon" silicon carbide bricks 0·00982. Relative to pressed fireclay (1·0), the conductivities are: sillimanite 2·1; magnesia 3·2; fused alumina 4·1; silicon carbide 4·8.

A QUANTITATIVE LABORATORY SLAG TEST.—F. H. Norton (*J. Amer. Cer. Soc.*, **7**, 599, 1924). Tests hitherto applied, *e.g.*, the immersion

of a complete brick in a bath of molten slag, melting the slag in a fireclay ring moulded on the surface of the refractory, or grinding known proportions of the refractory and the slag, and measuring the melting-point of the mixture, are not entirely satisfactory since they do not simulate actual working conditions. The resistance of a brick to slag is not solely dependent upon the penetration; the abrasive factor is also important. The test as now devised aims at producing an even flow of slag over one or more faces of the refractory specimen. This is done by introducing powdered slag into the air line of the burner, from which it is carried down into the test furnace with the flame, forming an even, constantly renewed coating over the test pieces. The latter are supported on a disc, and the molten slag is allowed to flow out through the bottom of the furnace. The volume of each specimen is measured before and after the test. Curves showing the percentage of each specimen remaining after a test, plotted against temperature, indicate that, on the whole, the results agree fairly closely with the behaviour of the bricks in practice. It is noted that a brick, which stands the slag test at a low temperature may have the least resistance at higher temperatures; *e.g.*, a magnesite brick was scarcely affected at 1,428°F., whilst at 1,593° it was practically destroyed. The chief advantage claimed for this method is the rapidity with which it can be carried out, even at high temperatures.

CHECKER BRICKS FOR RESISTING ALKALINE SLAGS.—M. C. Booze and F. C. Flint (*J. Amer. Cer. Soc.*, **7**, 594, 1924). Checker bricks, varying in physical and chemical composition, were placed in the top of regenerators of two glass tank furnaces in order to test their respective service values. The bricks tested ranged in composition from silica bricks to high alumina bricks and varied from a medium to a very dense texture. One of the furnaces was forced to maximum capacity, producing a temperature in the top of the regenerator of 2,000 to 2,200°F. The other was operated in a manner typical of the manufacture of the ordinary grade of bottle glass. The corresponding temperature in the latter instance was 983° to 1,093°F. The amount of corrosion was found to vary directly with the silica content of the brick. In the regenerator operating at the lower temperature, the corrosive dust appeared to have little action on the bricks high in alumina, whilst it fused to a glass on the highly silicious material. On the other hand, it adhered to the high alumina bricks and tended to clog the regenerator working at the higher temperature, and appeared to flux and drain off those high in silica.

A parallel series of laboratory tests was carried out by determining the fusion point of cones made from mixtures of the different bricks with varying percentages of the corrosive dust. The results agreed closely with those obtained in the service tests .

PATENT.

ELECTRIC INSULATORS.—Metropolitan-Vickers Electrical Co., Ltd. (*Pat. J.*, 1,765, 1922). No. 186,285, Mar. 21, 1922. A series of disc-like sections of solid insulating material with projecting circular flanges is held together by a flexible girdle which engages the adjacent flanges. The sections are hollowed out in the centre.

IV.—MANAGEMENT, ORGANIZATION, COSTING, ETC: COMMERCIAL.

THE CORRECT COSTING OF WASTE.—R. B. Hobson (*Ind. Man.*, **11**, 381, 1924). The prime rule in cost accounting is to charge the product direct with all costs that can definitely be said to belong to it. Considerable effort in the correct allocation of losses to the product is fully justified. When goods are manufactured in lots, or orders, the good parts must always stand the expense of spoilage and scrap, receiving the benefit of the salvage. Conditions in the pottery trade are cited as an example. The breakages which occur in the kilns are caused either by improper firing or by poor or incorrect

workmanship in a preceding operation. In practically all cases, spoilage due to poor workmanship is charged back to the department responsible, whilst losses due to poor firing are commonly charged to general manufacturing expenses. The correct method of costing in this case is to make the good units bear the expense of the poor or broken ones so far as breakage due to improper kiln firing is concerned. When a kiln is opened, a report is made of the number of good units, number to be re-fired, and number defective or broken. The cost of that defective ware which is due to bad workmanship in previous processes is charged back to the department concerned, whilst the loss due to bad firing is charged to the kiln department overhead costs. The total good units produced over a given period, *e.g.*, one month, thus bear the cost of all ware spoiled by the fault of the kiln department. The general rules for a system of charging waste and crediting salvage may be briefly stated as follows :—

I.—*Charge scrap and salvage directly to the part or lot*—(*a*) Where there is a wide fluctuation in the amount of scrap from the various lines of product. This is essential to accurate costing by lines ; (*b*) When the value is sufficiently high to justify the clerical expense involved in allocating the amounts ; (*c*) When the waste is due to poor product ; In any case where the amount of scrap can be allocated easily.

II.—*Charge scrap and credit salvage to overhead expense*—(*a*) When the loss is due to general manufacturing conditions ; (*b*) When the amount of scrap from all products of the plant is fairly uniform ; (*c*) When the value of the scrap is so small as not to repay the clerical work involved in its allocation.

HOW TO CONTROL GLASSWORKS EXPENSES.—S. T. Morris (*Glass*, **1**, 306, 1924). The types of expenses dealt with are : (1) Power, light and water ; (2) non-productive wages ; (3) stores ; (4) rates ; (5) insurance ; (6) stationery ; (7) stamps ; (8) travelling expenses ; (9) petty cash sundries. These are discussed briefly.

NEW ONE-MILLION-DOLLAR POTTERY.—(*Cer. Ind.*, **2**, 359, 1924). A description is given of the Homer Laughlin China Company's plant. The illustrations are numerous and good. The plant has 3 tunnel kilns, and all the equipment is of the most modern type.

V. GLASS: GENERAL.

NOTE ON COLOURED GLASSES.—A. Granger (*Chim. Ind.*, **11**, 408, 1924). Glass is now considered as a solid solution and not, as earlier workers (*e.g.*, Benrath, Weber, Zulkovski) attempted to prove, a definite chemical compound. The formation of coloured glass does not appear to obey any well-defined law. The red, so-called ruby gold glass owes its colour to metallic gold. The properly melted glass is colourless, and the red tint is only developed by reheating. Owing to the viscosity of the liquid, or better, to the lack of molecular mobility, the gold is not precipitated in the first instance, but, on gently reheating, the glass is rendered sufficiently mobile to allow the finely divided gold to spread throughout the mass. Yellow, brown, pink and red colours are produced in glasses by other elements also, *e.g.*, carbon, sulphur, selenium, either alone or in conjunction with other materials. Glasses coloured with copper, however, present a more complicated problem. The blue colour produced in glass containing copper oxide is the more pronounced, the greater the molecular proportion of alkalis to the divalent metallic oxides, which it is now customary to introduce into glass batches. It is noted incidentally that this blue colour is that of copper salts in solution. On melting a batch containing copper oxide together with a mild reducing agent (iron scale, tin oxide), a green glass is produced, the colour of which changes, upon reheating, to red, as in the case of the gold glasses. The author maintains that this red colour is due to metallic copper, and not, as is still sometimes supposed, to cuprous oxide. At high temperatures cuprous oxide is the

stable form. On cooling, the cuprous is converted into cupric oxide, metallic copper being deposited. The action of opacifiers is cited to show that certain transformations, which can scarcely be explained chemically, may take place in solid glass. Of the colouring agents commonly used at present, cobalt is the only one which has a purely chemical action. The anhydrous salts of cobalt are blue, and no change in colour is produced by reheating.

GOLD LETTERING ON GLASS.—(*Diamant*, **46,** 250, 1924). The parts to be treated are coated with 40°Ré waterglass solution, gold leaf being then applied and pressed on. The glass is then warmed over a spirit lamp to 36°C. in order to dry it a little. The lettering, or figures, are then outlined with a pencil, the remaining gold being lightly removed. The article is then fired to a higher temperature.

INSULATING GLASS TANK WALLS.—(*Cer. Ind.*, **2,** 349, 1924). According to W. K. Brownlee, insulation of a glass-melting tank causes a lower, and not higher, temperature of the refractory wall. Thorough insulation enables furnaces to be run at a lower temp. without reducing the capacity. Internal circulation of the molten glass, caused by the glass in contact with the walls of an ordinary furnace becoming chilled, is eliminated. A small, experimental tank furnace, in which 2½ in. sil-o-cel insulation was used, showed no sign of vertical corosion after working 30 days at 1,371°-1,428°F., indicating that the internal temp. had been so completely equalised that vertical currents were obviated.

RECIPES FOR GLASS ETCHING.—(*Diamant*, **46,** 247, 1924). Notes on the various methods of etching. The following 7 "baths" are given: (1) One part conc. hydrofluoric acid, 100 parts water are neutralised with potash, whereupon a further three-fourths HFl are added; (2) 100 water, 18 potassium fluoride, 1 H_2SO_4, 12 potassium sulphate, and 25 HCl; (3) 1,000 water, 8 potassium fluoride, 1 H_2SO_4; (4) 5 HFl, 8 ammonia, 10 potassium fluoride, 2 potassium sulphate, 40 water; (5) 1 part HFl is neutralised with soda crystals, the mixture being diluted with 5 of water; (6) 30 parts 50% HFl, 17 sodium acetate, 9 calcined soda; (7) 9 sodium fluoride, 10 conc. (100%) acetic acid. No 3 is the most active of the seven. A beautiful silky effect is obtained with No. 4.

GAS BURNERS IN THE GLASS INDUSTRY.—F. Huth (*Diamant*, **46,** 249, 1924). Special burners of the bunsen type, for working glass, are described.

UNBREAKABLE GLASS.—(*Diamant*, **46,** 250, 1924). The claims recently put forward in France and America are not new to the glass industry. Similar glass was produced at Jena in 1893.

THE WINEGLASSES OF THE XVIII. CENTURY.—F. Buckley (*Glass*, **1,** 297, 1924). An illustrated account of their development is given.

FORGERIES AND REPRODUCTIONS OF ANCIENT PAINTED GLASS.—F. S. Eden (*Glass*, **1,** 299, 1924).

THE PREPARATION OF COPPERED GLASS MIRRORS.—E. A. H. French (*Glass*, **1,** 301, 1924; from *Trans. Opt. Soc.*, Vol. **25,** 1924). A method for the deposition of copper on plate glass, in the form of a highly reflecting coherent film, with special reference to searchlight mirrors, is introduced. The results of a few of the principal experiments conducted during the necessary research are presented in detail. A lasting film is obtained, at comparatively low temperatures, by the use of hydrazine sulphate. Sketches and illustrations are given of the necessary apparatus. Nine grams of hydrazine sulphate are dissolved in 150 c.c. distilled water and heated to 60°C.; to this is added, with constant stirring, 90 c.c. of a saturated solution of copper hydroxide and ammonia at 16°. After being cleaned by a special process, the glass is first sponged over with this liquid. Then, without delay, 87·5 c.c. of a solution of 11·1 grs. potassium hydroxide to every 100 c.c. dist.

water, are added to the above mixture. The coppering process is carried out over a sand water bath within strictly defined limits of temperature. The process is considerably cheaper than that in which phenylhydrazine is employed. Furthermore, the use of hydrazine prevents the formation of scum and stains, and is much safer for the operator.

THE MICROSCOPIC IDENTIFICATION OF STONES IN GLASS.—H. Insley (*J. Amer. Cer. Soc.*, **7**, 14, 1924). Determinations of the optical properties of stones in glass by means of the polarising microscope affords more useful and reliable data than chemical analysis. A short description of the method of preparation of stones for microscopic examination is given. The paper closes with a list of the crystalline compounds occurring in the soda-lime glasses; the optical properties of each compound, the usual habit of the crystals, their associations, the different types of stones in which they occur, and the properties most useful for distinguishing them from other crystalline materials in glass being also noted.

RAW MATERIALS USED IN THE MANUFACTURE OF GLASS; RED LEAD.—C. J. Peddle (*Glass*, **1**, 292, 1924). The use of lead oxide in place of lime in glass batches was introduced in England early in the XVII. century, and it is to this fact that the fame of England as a glass-producing country was first built up. Prior to this period, Venetian potassium—calcium—silicate (*i.e.*, "lime") glass held the first place. "Lead" glasses differ from "lime" glasses in several important particulars: (1) potassium oxide is employed instead of sodium oxide as a fluxing agent, and lead oxide replaces that of calcium as the metallic ingredient; (2) the technique is different; lead glasses must be melted in an oxidising atmosphere. The lead can be introduced as lead mitrate, lead silicate, white lead, and the various oxides. The best method is to introduce one of the oxides, the most suitable being red lead, because it gives off oxygen during melting and is cheaper than lead dioxide. The process of manufacturing litharge and red lead, and the methods of testing for impurities are outlined.

METAL-TO-GLASS JOINT.—H. U. Kidyard (*J. Amer. Chem. Soc.*, **46**, 287, 1924). Glass, silica, or porcelain tubes are coated with a mirror of platinum, the coated end then being dipped into a molten lead bath. This causes a thin film of lead to adhere closely to the glass, and the tube can then readily be soldered into a suitable metal tube.

BATCHES FOR PLATE AND WINDOW GLASS.—(*Pot. Gaz.*, **49**, 1,042, 1924). Two patents by F. Gelstharp on modifications of sheet glass batches are discussed. The usual fining agent, sodium sulphate, is replaced entirely or partly by As_2O_3 or gypsum. Arsenic has the added advantage of producing a glass freer from seeds. The new and old formulæ are contrasted as follows:—

Batch	With Arsenic		With Gypsum	
	New	Old	New	Old
Sand	1000	1000	1000	1000
Soda ash	298	298	317	284
Salt cake	5	60	—	60
Sodium chloride ..	25	25	25	25
Limestone	309	309	268	309
Sodium nitrate ..	30	—	—	—
Charcoal	—	3	3	3
Arsenic	15	5	5	5
Gypsum	—	—	69	—

PATENTS

(GLASS) ANNEALING LEHR.—H. L. Dixon. *U.S. Pat. No.* 1,500,609, July 8, 1924. The lehr is of the muffle type, the walls of the heating chamber

being formed of resistance material of varying conductivity in different portions of the furnace.

GLASS-MAKING APPARATUS.—W. R. Smith. *U.S. Pat. No.* 1,500,651, July 8, 1924. The apparatus comprises a closed tank to hold the molten glass, and an elongated tubular melting tuyère, which extends through the wall of the tank. The inner end of the tuyère constitutes a burner, situated within the tank. Means are provided (*a*) for admitting air and gas under pressure to the outer end of the tuyère, and (*b*) for delivering batch materials to the flame at the burner. The molten batch collects at the bottom of the tank below the burner.

FORMING SILICA-GLASS ARTICLES.—E. R. Berry (*Pat. J.*, 1,848, 1924). No. 214,630, Apr. 15, 1924. Relates to the manufacture of tubes or rods by extension. In order to prevent the diameter of the rod becoming reduced at the aperture owing to the weight of the suspended portion, the latter is counterbalanced by being extended into a liquid of approximately the same sp. gr. as quartz, *e.g.*, a salt solution, sulphuric acid, carbon tetrachloride.

DRAWING GLASS SHEETS.—J. B. Best (*Pat. J.*, 1,851, 1924). No. 215,750, May 5, 1924. According to the invention, means are provided for introducing wire netting or colouring matter into the body of the sheet and for cutting the sheet into sections.

DELIVERING MOLTEN METAL.—A. McNish (*Pat. J.*, 1,851, 1924). No. 215,817, Feb. 9, 1923. Relates to automatic feeders of the reciprocating plunger type. A reciprocating cam is used to impart the required motion to the plunger.

GLASS BLOWING.—Europ. Verband Flaschenfabriken Ges. (*Pat. J.*, 1,852, 1924). No. 216,164, May 19, 1924. Relates to means for enabling bottles of different heights to be made simultaneously on a machine of the Owen's type.

PRODUCTION OF METAL.—F. M. Oppermann (*Pat. J.*, 1,852, 1924). No. 216,494, Feb. 26, 1924. A pot of metal is allowed to cool from the refining temp. to the working temp. in an apparatus which is separate from the refining furnace and also from the batch melting furnace, and which consists of a tunnel heated similarly to the usual form of lehr.

GLASS ROLLING.—Pilkington Bros and E. B. Le Mare (*Pat. J.*, 1,853, 1924). No. 216,586, Mar. 2, 1923. On issuing from the tank furnace the strip of glass is drawn over a flat bed on its way to the lehr. The stationary bed is of such length, that the plastic strip becomes flattened and sets before it passes on to the rollers in the lehr.

PREPARATION OF ALUMINA; ALKALI ALUMINATES; DOUBLE SILICATES, ETC.; GLASS-MAKING.—K. L. Frink (*Pat. J.*, 1,851, 1924). No. 215,810, Jan. 15, 1923. Aluminium silicates, *e.g.*, kaolin, clay, shale, coal refuse, and felspar, are mixed with an alkali chloride and an alkaline earth and brought to reaction temp. in an atmosphere containing water-vapour, such as glass-furnace gases, which contain, in addition, sulphur and carbon oxides. The reaction product is leached with water and the insoluble material, which may be calcium silicate or calcium aluminium alkali silicate may be used in glass making. The solution is treated with the heating gases, which decompose the alkali aluminate, precipitating alumina, which is separated. The remaining solution consists of alkali carbonate and sulphate, and the mixed salts may be used in glass making, or may be converted into carbonate by known methods. A sketch illustrates the arrangement of a suitable plant.

GLASS BLOWING.—K. Bartl (*Pat. J.*, 1,853, 1924). No. 216,779, Oct. 24, 1923. The blower is fitted with a handle, one end of which is connected to a supply of compressed air. A valve is fitted in the handle, enabling the blower to control the admission of air to the pipe.

GLASS BLOWING.—Empire Machine Co. (*Pat. J.*, 1,857, 1924). No. 21,810, July 9, 1923. A machine for making thin, hollow glassware is described.

DELIVERING MOLTEN METAL.—W. S. Pratt, for C. H. Rankin (*Brit. Pat.* 218,888, 1 Oct., 1923). The receptacle, which has an orifice in its lower part through which the glass is discharged, the plunger, movable in alignment with the orifice, and a controlling tube, which dips into the glass in the receptacle, are rotated at the same angular velocity, so that, as the molten glass runs into the receptacle, it is distributed around the plunger, ensuring an even distribution of temperature in the column of glass leaving the orifice.

FORMING HOLLOW-WALLED GLASS VESSELS.—Glasfabrik Saphienhütte R. Bock Ges., and W. Hodecker (*Brit. Pat.*, 219,893, 26 Feb., 1924). The method of making vacuum flasks consists in blowing a hollow glass body to the shape of the finished outer walls of the flask, and providing a domed portion thereon, which is pushed inward and shaped to form the inner wall.

BOROSILICATE GLASS.—Schott and Gen (*Brit. Pat.*, 219,972, 25 July, 1924). Glasses particularly intended for optical purposes, have the alkali content mainly in the form of potash. They may contain 4 to 18% of boron trioxide, not more than 10% alumina, from 3 to 19% potassium oxide, the remainder being silicon. Lead oxide or baryta may be present to the extent of 35%. The lead may be replaced partly or entirely by antimony, and the baryta by lime, magnesia, or zinc oxide.

DELIVERING MOLTEN GLASS.—S. G. S. Dicker, for Owens Bottle Co. (*Brit. Pat.*, 219,165, 9 July, 1923). The device consists of a receptacle having a discharge aperture at the bottom, over which is depended a plug or regulator. Both the plug and the receptacle can be rotated in order to cause the glass to move round the axis of the discharge opening.

SHAPING GLASSWARE AFTER FORMATION.—British Thomson-Houston Co., Ltd., for C. A. Brown and A. C. Nielson (*Brit. Pat.*, 219,677, 11 July, 1924). Relates to means for severing blown glass articles, such as electric lamp bulbs, from the tubing or the surplus neck portion to which they are attached.

GLASS BOTTLES AND STOPPERS.—Schott & Gen. (*Brit. Pat.* 219,680, 12 July, 1924). A series of glass stoppers of graduated sizes is made for each outer width of the neck of the bottles, and the inner part of the neck is ground off until the stopper, the diameter of which exceeds the neck least, fits into the bottle. The stopper can thus be made cheaply by blowing and pressing.

METHOD OF, AND APPARATUS FOR MELTING GLASS.—E. C. R. Marks (for The Libbey Glass Co.) (*Brit. Pat.* No. 218,718, Apr. 5, 1923.) A method and apparatus are described, which permit of producing and maintaining a uniform temperature in the pool from which the glass is worked or gathered.

DRAWING GLASS.—Pilkington Bros. and D. Railton (*Pat. J.*, 1,856, 1924). No. 217,736. Apparatus is described for drawing glass sheets. The metal is conducted from below the surface of the molten mass through two channels to the two sides of the line of draw, in order to secure an even temp. on both sides of the sheet at the drawing point.

GLASS BLOWING.—E. A. Hailwood (*Pat. J.*, 1,858, 1924). No. 218,452, May 28, 1923. A mould for forming flanged articles is made in two parts, movable in relation to one another, in order to squeeze together portions of the blown article.

VI.—CEMENT, CONCRETE, MORTARS, ETC.

CEMENT AND LIME INDUSTRY OF ESTHONIA.—(*Rock Prod.*, **27**, No. 15, 1924). Esthonian soil is particularly rich in lime and clay; con-

sequently, the conditions are unusually favourable to the development of the cement industry. Exports in 1922 trebled those of 1921, the chief customers being Latvia, Scandinavia and Germany.

GERMAN EXPERIENCE WITH ESTRICH GYPSUM OR FLOORING PLASTER.—(*Rock Prod.*, **27**, No. 15, 1924). According to P. P. Budnikov, estrich gypsum is prepared by heating gypsum above 800°C. Dissociation of $CaSO_4$ begins at 750-800°. Free CaO can be distinguished under the microscope, and it is this which gives flooring plaster its special properties. This is confirmed by adding 2 to 5% CaO to plaster of Paris. F. A. Wilder suggests the term "hydraulic gypsum," to describe the German product. These hydraulic gypsums are different from Keene's cement and other dead-burned gypsum cements manufactured in America.

THE DESTRUCTION OF CONCRETE BY SEA-WATER.—O. Gassner (*Tonind. Ztg.*, **48**, 467, 1924). The literature on the subject is reviewed at some length under the headings :—(1) General ; contradictions ; sea-water. (2) Development of the Michaelis theory of destruction. (3) Other and similar explanations which (*a*) contradict, (*b*) support this theory. The references in the literature are characterised as being as numerous as they are contradictory.

HIGH-GRADE CEMENTS.—H. Luftschitz (*Tonind. Ztg.*, **48**, 577, 1924), A general discussion of the various high-grade cements (ciment fondu, alumina cement, electric cement, etc.).

SOME REQUIREMENTS IN THE STUDY OF PORTLAND CEMENT.—T. Merriman (*Rock Prod.*, **27**, Nov. 15, 1924). The search for better concrete renders necessary a careful investigation into the characteristics of its most important ingredient, Portland cement. As is the case with steel, different grades of cement ought to be available in order to meet particular needs. Seven characteristics of an ideal cement are listed. The result of certain investigations is promised for a later date.

CALCIUM FERRITES—BARIUM FERRITES.—E. Martin (*Chim. Ind.*, **11**, 406, 1924). The work forms part of a general study of the constituents of cements. The barium compounds are introduced merely because they are more easily prepared than the calcium ferrites, barium oxide being more readily soluble than lime. A brief account is given of the methods of preparing ferrites (1) with water ; (2) at high temperature. While experimenting with the latter class, the author prepared a cement which resisted the action both of sea water and of calcium sulphate solution. This cement is about to be patented, and will form the subject of a later paper. The ferrite formed on heating a mixture of $CaCO_3$ and Fe_2O_3 to a temperature below fusion point, depends upon the proportion in which the ingredients are mixed, and not upon the temperature attained ; *e.g.*, on heating the mixture : $Fe_2O_3 + CaCO_3$ to a temperature not exceeding 1,200°, the monocalcic ferrite Fe_2O_3, CaO is obtained, whilst under similar treatment the mixture $Fe_2O_3 + 2CaCO_3$ gives the bicalcic ferrite Fe_2O_3, 2CaO. The powder obtained from the former reaction has a density closely approximate to 4. It is magnetic and non hydraulic. Ten per cent. sugar solution has no action on the monocalcic ferrite. It is insoluble in 10% acetic acid, in sodium carbonate solution, and in ammonium chloride solution, either hot or cold. It is slightly soluble in lime-sugar solution, and is attacked slowly by oxalic acid. Excess of alumina decomposes the ferrite at high temperatures (1,200°), whilst with silica, silico-ferrites are formed. On heating a mixture of Fe_2O_3, $CaO + SiO_2$ to a temperature below fusion point, a product is obtained having properties corresponding neither to the original ferrite nor to calcium silicates. This reaction is the subject of further study, and results will be published later. The bicalcium ferrite—Fe_2O_3, 2CaO—resembles the monocalcic in chemical behaviour, except that it is attacked slowly by 10% acetic acid. It is also slightly soluble in boiling sodium carbonate solution and is entirely decomposed in ammonium chloride solution. The ferrites formed by *fusing* the above

mixtures differ in their properties from the preceding. That resulting from the fusion of the mixture $Fe_2O_3+CaCO_3$ has a density slightly below 4, and is magnetic. Its hardness is represented by 6 on the Mohs scale. The fused ferrite is attacked slightly by water whilst 10% acetic acid dissolves out a large proportion of the lime. Similar results are shown by the ferrite formed by fusing the mixture $Fe_2O_3+2CaCO_3$.

PATENTS

PREPARATION OF REACTIVE BLAST-FURNACE SLAG.—R. Grün (*Ger. Pat.* 395,958, 24 Feb., 1921). Acid, non-reactive blast-furnace slag, in a molten condition, is heated in a carbon electric furnace, CaO or other lime compound being added during the process. Chlorides or fluorides may also be added. The product may be used in making mortars, or may serve either as the hydraulic flux or as the raw material for artificial stone.

CONVERSION OF ACID BLAST-FURNACE SLAG INTO PORTLAND CEMENT OR INTO BASIC SLAG FOR THE MANUFACTIRE OF BLAST-FURNACE CEMENT.—R. Grüm (*Ger. Pat.* 396,025, 30 July, 1921). In the process of making Portland cement or basic slag by the addition of CaO, premature hardening is avoided, and the mass maintained in a sufficiently fluid condition, by adding sesquioxides to the molten blast-furnace slag. The whole of the sesquioxide may be added before the lime, or alternatively, a portion only may first be added, followed by simultaneous, or alternate additions of CaO and sesquioxides, care being taken to avoid the formation of refractory compounds.

CONTROLLING THE SETTING TIME OF FUSED CEMENTS.—A. Guttmann (*Ger. Pat.* 397,086, 25 June, 1922). Rapidly cooled melts are mixed in definite proportion with slowly cooled melts, and ground to produce a cement having the desired setting time, the latter, in the case of fused cements, depending upon the rate at which the melts have been cooled.

MANUFACTURE OF POROUS BRICKS.—H. Koppers (*Ger. Pat.* 396,691, 6 Mar., 1923). Solutions of suitable materials, such as soap, are added to the clay slip, the mixture being thoroughly agitated. The added solution reduces the surface tension of the water, producing a slip with a high foam-holding capacity. Air may also be blown in to increase the porosity of the mass. Bricks made by this method have a low sp. gr., a low thermal conductivity, and high refractoriness.

PREPARATION OF FUSED CEMENT.—A. Groebler and A. Guttmann (*Ger. Pat.* 399,456, 22 July, 1924). The fusion process is carried out in an electric induction furnace. The temperature of the melt can be regulated, and the limestone may be added in an unground condition.

METHOD OF PRODUCING A HYDRAULIC CEMENT AND ARTIFICIAL STONES FROM BITUMINOUS SHALE-SLAG.—O. Schmidt and M. Hahnle (*Brit. Pat.* 221,017, 4 Sept., 1924). Oil-shale is burned at a temperature below sintering point and the slag so obtained is ground to the fineness of cement together with burnt marl of suitable composition, or with cement and the addition, if desired, of suitable hydraulic substances, such as granulated blast furnace slag. A suitable quantity of anhydrous sulphate of lime may be added in the grinding. In the production of artificial stones, the previously broken up shale-slag is divided into a fine and a coarse portion, the latter being employed as filling material for artificial stones, while the former may be further treated separately for the production of the cement.

PREPARATION OF LOW-FIRED CEMENT.—H. Kühl (*Ger. Pat.* 399,446, 22 July, 1924). The mixture consists of raw materials containing lime and clay, together with a small percentage of finely ground fluorspar, the lime content being intermediate between that of Roman cement and Portland cement. The mixture is heated to a temperature a little above that required to expel the CO_2. The product possesses better storage qualities than the corresponding Portland cement.

MANUFACTURE OF ARTIFICIAL STONE.—Jura Oelschieferwerke A.G. (*Ger. Pat.* 377,451, 9 July, 1920). Addition to German Pat. 376,606. The shale employed as a filler is used in a finer condition, and is heated to slightly over 800° to expel the CO_2. This method has the advantage over the original of preventing premature drying, thus giving a product of greater strength.

MANUFACTURE OF CEMENT-LIKE MORTAR-FORMING MATERIAL. —H. Becker (*Ger. Pat.* 396,932, 9 Oct., 1920). A mixture of CaO and silicates is heated and withdrawn from the furnace as soon as fusion point is reached. It is then allowed to cool, and ground. A homogeneous fused mass is not desired ; portions of the ingredients (SiO_2, etc.) remain undissolved.

NEW DIATOMACEOUS EARTH PRODUCT.—R. Calvert, K. L. Dern and G. A. Alles (*U.S. Pat.* 1,502,547, 22 July, 1924). The new product consists of a calcined finely-divided mixture of diatomaceous earth and a halide of an alkali-forming metal. The mixture is calcined at a temperature sufficiently high to sinter the siliceous dust in the material, but not high enough to sinter the mass.

IMPROVED HARD-GRAINED CONCRETE.—Metallochemische Fabrik A.G. (*Ger. Pat.* 395,766, 14 Dec., 1922). Metals, such as Pb,Zn, Sb, Cd, etc., or alloys, are added in powdered or granulated form to concrete, which is then particularly suitable for steps, workshop floors, etc.

BUILDING MATERIAL AND METHOD OF MANUFACTURING SAME.—R. W. Strehlenert (*U.S. Pat.* 1,501,975, 22 July, 1924). A mixture of clay, wood cuttings and waste sulphite liquor is converted into a mass of granular consistency by the addition of a small quantity of water, moulded under pressure, and heated rapidly to 200° or over for a short period, in order to decompose partially the sulphite liquor and render the stone hard and not hygroscopical.

SYNTHETIC MINERAL ASPHALT AND METHOD OF MANUFACTURING THE SAME.—A. G. Saunders (*Brit. Pat.* No. 218,750, Apr. 13, 1923). The mixture consists of finely-divided carbonate of lime and a bituminous or tar base. The viscosity of the synthetic asphalt is controlled by the addition of resin (in substantial quantities) and a thin mineral oil, the former increasing and the latter lowering the viscosity. Five examples of mixtures are given.

COLOURING CONCRETES, MORTARS, ETC.—Master Builders Co. (*Pat. J.*, 1,856, 1924). No. 217,633, Mar. 13, 1923. The pigment, or dyed kieselguhr, is ground in calcium chloride solution to produce a paste, which is mixed with the water used for gauging the concrete.

PULVERULENT FUELS ; CEMENTS.—E. Bouchaud-Praceiq (*Pat. J.*, 1,857, 1924). No. 218,075, May 17, 1923. Modification of Parent Spec. 173,504. The fuels, and, if necessary, the additional substances, are mixed in such proportions that the product after burning at 1,400-1,800°C. is substantially in accordance with the formula : $2(Al_2O_3.CaO) + SiO_2.CaO$, so as to obtain a "molten cement." The hard-set ashes are broken up and crushed.

MAKING CONCRETE BLOCKS.—Soc. Veuve Bonnet, Aîné et ses fils (*Pat. J.*, 1,851, 1924). No. 215,774, May 8, 1924. Relates to automatic ejection apparatus in machines for moulding concrete, etc.

MOULDING CONCRETE CENTRIFUGALLY.—C. W. Watson (*Pat. J.*, 1,854, 1924). No. 217,227, June 26, 1923. A machine for moulding reinforced or plain concrete pipes or other hollow bodies is described.

WATERPROOF CONCRETE AND MORTAR.—C. Pickstone (*Par. J.*, 1,855, 1924). No. 217,388, May 2, 1923. From 5 to 20% of the sand or other inert material is replaced by fine slate dust to render concretes and cement mortars waterproof and to increase the strength.

CASTING CONCRETE.—J. T. Wisner (*Pat. J.*, 1,849, 1924). No. 214,977,

Apr. 14, 1924. In casting wet concrete the mould frame is provided with a liner of rigid, absorbent material (strawboard) adapted to support the material during setting and to permit the removal of the mould frame.

ROTARY BATCH-MIXERS.—P. D. Ionides and Ransomes & Rapier, Ltd. (*Pat. J.*, 1,849, 1924). No. 215,093, Feb. 2, 1923. The machine described—for making concrete, mortar, etc.—provides for first moistening the aggregate and then incorporating with cement, which is introduced into a mixing drum in the form of a fine mist or cloud.

PORTLAND CEMENT.—L. E. W. Pioda (*Pat. J.*, 1,850, 1924). No. 215,357, Apr. 29, 1924. Apparatus is described for making cements from clay or silt, which is found in such a fine state of division, that grinding is unnecessary, and particularly from such deposits containing shells. For utilizing submerged deposits, the apparatus is mounted on a barge.

MIXING CONCRETE.—A. W. Rybeck (*Pat. J.*, 1,848, 1924). No. 214,633. Apr. 16, 1924. Relates to rotary batch mixers of the portable, tilting type,

TREATING CEMENT KILN GASES.—Babcock & Wilcox (*Pat. J.*, 1,848, 1924). No. 214,779, Feb. 24, 1923. Relates to the separation of dust from gases and treating gases with liquids. Dust laden gases are caused to deposit the solid contents in caked form on the heated walls of flues provided with baffles.

ARTIFICIAL STONE COMPOSITION.—Soc. Internationale Marmorit (*Pat. J.*, 1,849, 1924). No. 214,947, Dec. 28, 1923. A substance containing more than 42% magnesia is calcined at a temp. above 1,600°, ground, and mixed with powdered quick-lime in the proportion of 4·5 parts magnesia to 1 of quick-lime. A solution of magnesium chloride of 20-30° Bé is added, fine sand or chalk and colouring matter is worked in, and the mass is moulded at a temp. above 20°C. for 48 hours.

VII.—CHEMICAL AND ANALYTICAL PROCESSES.

ANALYSIS OF BASIC BRICKS.—"Kaolin" (*Brit. Claywr.*, **32**, 294, 1924). Details are given of a method of analysing basic bricks without the use of special chemicals such as are not usually found in works laboratories. The sample should be ground to a fine powder and stored in an air-tight vessel so as to prevent absorption of moisture and CO_2 from the atmosphere. A typical analysis of a basic brick is as follows :—lime 58·65% ; magnesia 36·70% silica 1·86% ; ferric oxide 1·30% ; alumina 0·84%.

VIII.—HISTORICAL, EDUCATIONAL, INSTITUTIONS, ETC.

NYMPHENBURG PORCELAIN.—(*Ker. Rund.*, **32**, 451, 1924). An illustrated review of the third volume of F. H. Hofmann's work : "Geschichte der bayerischen Porzellanmanufaktur Nymphenburg,"

THE BUNZLAU CERAMIC INDUSTRY.—Berge (*Ker. Rund.*, **32**, 455, 1924). The progress made since 1911 is reviewed, special attention being devoted to the effect of the war on the industry of the Bunzlau district.

FLINT DUST AND SILICOSIS IN POTTERIES.—T. M. Legge (*Pot. Gaz.*, **49**, 1,365, 1924). A résumé of the Report of the Senior Medical Inspectors for 1923. Reference is made to Middleton's determinations of dust, for which purpose an Owen's dust counter was used. In two of the records,

the dust counts gave slightly over 1,000 particles in 1 c.c. Cyclone separators gave high counts of dangerous flint particles. In 8 settling chambers, there was leakage of dust, indicating a positive pressure within the chamber. Exhaust systems of ventilation appeared to fail in all except two cases. The essential requirements of such systems are indicated. From 3,000 to 4,000 particles of fine silica dust per c.c. were found in the atmosphere of silica rock quarries, *i.e.*, about 10 times the amount of dangerous dust found in sand quarries. The shape of the quartz grains has no bearing upon the dangerous character of the dust. The important points are : the size of the particles and the presence of sufficient moisture, with or without clayey matter, to fix the fine silica particles before they are inhaled. Clay diminishes the danger from the inhalation of silica dust. Microscopic examination showed that many of the quartz particles were attached to small masses of plastic clay, which tended to produce clumping, thus reducing the number of free particles. The investigations showed that, the higher the proportion of free silica in the raw material, the greater is the danger of the production of fine silica dust, with consequent injurious effects upon the health of employees

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Reviews.

Lime and Magnesia.

By N. V. S. Knibbs. Pp. 306. London: Ernest Benn, Ltd, 1924. Price, 30/- net.

The *raison d'être* of this volume is the collection and collation of data concerning the chemistry, manufacture and uses of the oxides, hydroxides and carbonates of calcium and magnesium. The author has made a commendable effort to satisfy the requirements of the lime-burning and allied industries, and is to be congratulated on his attempt to make the volume useful in those industries, where lime and magnesia products are of prime importance. Further, the author can certainly claim to have indicated where useful technical research in many branches of the manufacture and utilization of lime and magnesia can be undertaken with success.

The book opens with a discussion of the chemistry of the materials under consideration. With the aid of Mellor's "Comprehensive Treatise," (which help is suitably acknowledged), the author has been able to collect a voluminous amount of data concerning the chief chemical and physical properties of the purer materials. Full references are given and, consequently, this section forms an admirable basis for the consideration of the technical problems of the manufacture and uses of the various products. It is felt, however, that this portion could have been reasonably enlarged by a concise discussion of the chemistry of the more important reactions occurring in the utilization of lime in industry. For instance, it seems particularly apposite to the metallurgical use of lime that the stability relations of CaO, Al_2O_3 and SiO_2 should be briefly included. The data given for the thermal conductivity of magnesia material (p. 68), is misleading, and, in some cases, misquoted. Thus, Tadokoro and Wologdine obtained much higher values for the conductivity of magnesite brick. It is unfortunate that the author has not inserted a short note on the effect of aggregation on the conductivity of magnesia material, since it is a fact that while magnesia alba and very finely-divided magnesia are used as thermal insulators, magnesite bricks are comparatively good conductors of heat. On p. 69, the author states that the eutectic point of magnesium carbonate has not been determined. Surely, this is not surprising ! !

The second section of the book includes the mining and quarrying of the raw materials, the manufacture of the various industrial products, particularly of lime, of caustic and of dead-burnt magnesia. Possibly, this is the best portion of the book, for here, the author shows an admirable knowledge of the technique of these industries. Many photographic representations of the plant are included. Although in the main, these illustrations are very well produced, there has been a great waste of space in reproduction, adding, no doubt, to the cost of this fairly expensive volume.

The author has not been very successful in his discussion of the uses of lime and magnesia products. This task, to be thoroughly exploited, requires far more space than was apparently available to the author. The result has been that, except in the case of the use of lime in agriculture and in building construction, a few lines suffice to indicate very large fields of application. Magnesite refractories are dismissed in half a page, the metallurgical uses of lime in less than a page, while the use and abuse of lime in ceramics is told in eight lines! After a full appreciation of the space problem, it seems a pity that the metallurgical and refractory uses of the materials have not been considerably extended, and further, a selection of references concerning the technical applications and behaviour of these materials in practice, has not been appended. This section, however, indicates an important fact, "that limes of practically identical composition often behave quite differently when employed for the same purpose." And so with clays! This, certainly, indicates the necessity of technical research.

The author has produced a particularly useful, and highly readable book, which, with a few reservations, fills admirably a gap, that has long existed in technical literature.

A. T. GREEN.

Boric Oxides as a Constituent of Glass.

Arranged and Compiled by H. GOULDING-BROWN. Pp. 47.
(London: Borax Consolidated Ltd., 1924).

This brochure has for its object the presentation in a concise form, of interesting information for those engaged in manufacture of glass, especially of resistance glass. The material under discussion is, as the title suggests, boric oxide, and its influence on the durable properties of glass. Valuable data, concerning the coefficient of expansion, the strain, thermal and mechanical endurance and the resistance of various glasses to the effect of different chemicals are critically explained and discussed. The main portion of these data is obtained from the original papers in the Transactions of the Society of Glass Technology and the Bureau of Standards, and from tests conducted in the Department of Glass Technology, Sheffield University. From the facts presented there seems to be little doubt that, with reasonable control, the durability of glass is materially improved by the addition of boric oxide. A reference list of useful technical papers is appended.

The publishers of this booklet state that they will be willing to post copies to members of the Ceramic Society, on request.

A. T. GREEN.

PUBLICATIONS RECEIVED.

Aide-Mémoire de Céramique Industrielle. By ALIX CORNILLE pp. 184, (Paris: Revue des Matéraux de Construction et de Travaux Publics, 1924). Price: Frs. 22·50.

In the first part of this book, the author outlines in a simple manner the general principles underlying the technique, and the various methods of control applied in ceramic practice. In Part II. the different ceramic products

are classified on the basis of two characteristics : their chemical composition and the firing temperature. The book contains 70 illustrations, and a bibliography of French works on ceramics is given at the end. F.S.

Lehrbuch der Keramik. By Dr. H. Hecht, Pp. 336, 96 illustrations. (Berlin: Urban aud Schwarzenberg, 1923).

The book represents a valuable contribution to ceramic literature from the pen of a leading German expert. The author's object is to treat the whole subject of ceramics in a comprehensive manner and thus present a complete survey of this branch of industry. Commencing with the physical and chemical properties of the raw materials, due consideration, based on practical works experience, is given to the occurrence and formation, extraction and preparation of clays, to the compounding of the various bodies, glazes and colours, and to the making and firing of the different types of ware. Particular attention, from the modern, scientific point of view, is paid to practical difficulties arising in the manufacture of the different clay products. The work, undoubtedly, takes high rank among the practical treatises on ceramics ; and it is probably the first to present in a small compass, a comprehensive treatment of the whole subject. F.S.

Technische Fortschrittsberichte. Band I.—Keramik. By E. P. Bauer. Pp. XI. and 143. (Dresden and Leipzig: Th. Steinkopff, 1923). Price 4s.

The object of these *Berichte* is to present, in a clear and concise form, the latest developments and the progress made in the several branches of chemical technology. They therefore consist essentially of a systematic compilation of recent literature on the respective subjects. In volume 1. dealing with Ceramics, an attempt is made to include the more important references subsequent to 1914, but the author has not hesitated to refer back, where necessary, to earlier literature. A certain amount of judicious selection was inevitable in a book of this size ; one or other of the branches of a subject so extensive as that covered by the term Ceramics had, of necessity, to be treated with great brevity in a volume of approximately 150 pages. However, this little work should prove of great value as a book of reference, the primary object for which it was written. F.S.

Grundzüge der Keramik. By Dr. W. Pukall. Pp. 187, (Coburg: Müller and Schmidt, 1922).

In contrast with the two books referred to above, this work is intended to be of practical use in the laboratory both to the instructor and to the student of pottery. It has been compiled, as the result of many years of experience in the comparatively new sphere of ceramic instruction, on a chemical basis. It is not, therefore, a mere recipe book, but is intended to stimulate the creative faculty in the individual student, and to equip him with a sound knowledge of the principles of ceramic technique. The first, or general section, deals with raw materials, their occurrence, preparation, methods of testing, etc., whilst Part II. is devoted to special sections on (i.) ordinary clay wares (bricks, tiles, drain-pipes, flowerpots, firebricks, etc. ; (ii.) stoneware ; (iii.) earthenware, and (iv.) porcelain. F.S,

Minerals of the Empire. Imperial Mineral Resources Bureau. (Wembley: British Empire Exhibition, 1924). Price 5s.

Talc and Soapstone—Their Mining, Milling, Products and Uses. R. B. LADOO. Pp. 130. (Washington: Government Printing Office, 1923).

La revue générale des colloides et de leurs applications industrielles.

A new journal, issued monthly under the above title, has recently made its appearance in France, dealing specifically with colloids and their industrial application. This is the first periodical to appear in France which is devoted entirely to the study of colloids, the importance of which is increasing from day to day in industrial technique. Original articles appear each month and, in addition, abstracts are given of all the literature on the subject, under 24 headings. Division V. deals with glass making, clays, pottery, lime, cement, plaster, and constructional materials. Colloidal chemistry is of quite recent development; hence the new publication should prove of great interest to the majority of manufacturers.

Abstracts.

I.—RAW MATERIALS.

OCCURRENCE, PREPARATION, ETC.

TYPES OF MAGNESITE DEPOSITS AND THEIR ORIGIN.—G. D. Bain (*Econ. Geol.*, **19**, 412, 1924). An outline of the properties, preparation and uses of magnesite precedes an account of the occurrences and economic importance of the mineral deposits. Magnesite is sold in 4 forms: crude, caustic calcined, dead burned, and clinker. Dead burned magnesite is used chiefly as a refractory, its high m.p. and relative chemical inertness rendering it particularly suitable for this purpose. Magnesite is also used in the manufacture of oxychloride or Sorel cement. Other uses depend upon the magnesium content rather than upon the physical properties. Four main types of deposits are described: Magnesite as (1) a sedimentary rock; (2) an alteration of serpentine; (3) a vein filling, and (4) a replacement of limestone and dolomite.

REFRACTORY MATERIALS PRODUCED AT THE KANAKURA MINE.—Anon (*J. Jap. Cer. Assoc.*, **32**, 251, 1924). A white mineral, called "Toa-hakuseki," is produced with diaspore at the Kanakura mine in Shimotakai-gun, Nagano Prefecture. Both minerals are considered as decomposition products of porphyrite. An analysis of the "Toa-hakuseki," reported by the Imperial Geological Survey, is as follows: Water 24·28, silica 39·38, ferric oxide 0, alumina 36·94, lime 0, magnesia, trace and alkalies nil. It is very probable that the mineral is Newtonite ($Al_2O_3.2SiO_2.4H_2O+aq.$) contaminated with a small proportion of diaspore ($Al_2O_3.H_2O$). A greenish "Roseki" (meaning "wax-clay"), found under the diaspore, has the following composition:—

	Ig. loss	Silica	Alumina	Ferric oxide	Titanic anhydride	Lime	Magnesia	Total
(1)	6·83	58·66	32·25	trace	1·88	0·65	trace	100·27
(2)	8·38	58·77	29·40	,,	4·18	2·15	,,	99·88

PREPARATION AND REFINING OF TITANIUM OXIDE.—Tamaki Matsubara. The Osaka Industrial Laboratory. *Bulletin* IV., No. 13, 16, 1923). Recently, a titanium ore was found in Korea. An analysis is: Titanium oxide 25·90, silica 4·58, ferric oxide 58·85, alumina 1·10, lime 4·08 and magnesia 3·60. Titanium oxide was prepared by the known method, in which titanium-bearing ores are decomposed with conc. sulphuric acid. The results indicate that the ore must be ground as finely as possible, and also that too much sulphuric acid reduces the yield of titanic acid. Various processes of refining the crude oxide have been tried. Dehydration of refined titanic acid at temperatures over 400° is injurious, since yellowish tints are produced. S. Kondo.

PHYSICAL AND CHEMICAL PROPERTIES, TESTING, ETC.

DETERMINATION OF THE VALUE OF CHINA CLAY FOR FINISHING PURPOSES.—P. Bean (*Chem. Age, China Rev. Sect.*, **10**, 11, May 17, 1924). China clay for finishing purposes should be tested for grit, "feel," colour, lime, iron, organic matter and added blue. These tests are briefly described.

THE COMPOSITION AND PROPERTIES OF CLAY.—A F. Joseph and J. S. Hancock (*J. Chem. Soc.*, **125,** 1,888, 1924). The composition of a number of clays (chiefly soil clays), is recorded and the correlation between physical and chemical properties and composition is studied. The term "clay" denotes that portion of the raw material which remains suspended in a column of water 10 cm. high for 8 hours. The clays examined include English china and ball clays, Bentonite, and Egyptian potting clays and soil clays. The ultimate analyses showed wide differences in chemical composition, the most important characteristic being the silica-alumina ratio, which appeared to be connected with essential clay properties, being low in non-plastic and high in plastic materials. Plasticity being a property which is affected greatly by the action of heat and electrolytes, it is tentatively suggested that some property, possessed by all clays, might be chosen and the effect of these two factors in modifying it taken as affording a practical means of measuring plasticity. The same ratio seems related to the chemical reactivity of different clays to sodium hydroxide and neutral electrolytes.

THE EFFECT OF HEAT ON REFRACTORY CLAYS AND MIXTURES THEREOF.—Shinzo Satch (*Science Reports of the Tohoku Imperial University.* Series III., Vol. 1, No. 3,157, 1923). I. Thermal expansion and contraction. Dried specimens formed by moulding plastic masses of three typical clays, having the following composition, were used.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	KNaO	Ignition Loss	Air shrinkage	Refractoriness
A—Mitsuishi Roseki	43·30	48·16	0·26	0·26	0·01	1·52	3·02	1·4	Cone 54
B—Owarl .. plastic shale	48·02	34·02	1·93	0·54	0·17	0·54	15·35	8·2	Cone 33
C— Mino plastic kaolin	52·20	33·84	1·81	0·43	0·03	0·70	11·63	6·4	Cone 31

Clay *A* expanded gradually with a rise of temp. up to 700° ; after remaining constant to 900°, the expansion began to decrease and became zero at 1,180°. Then the contraction increased rapidly. The curve of clay *B* shows a slight contraction at the beginning of the heating and a slight expansion at 300°-580°. Such an initial contraction is not shown in the curve of clay *C*, which shows only a slight expansion at 300°–550°. Thus, according to its firing contraction, raw refractory clay may be classified in two types, one of which expands at low temps., while the other contracts without a marked expansion. To test the mixture, specimens were cut from green glass pots, which had been made of the three clays and broken pots. The result indicated that firing contraction of a clay mixture is a resultant of contraction of the constituent clays. The shape of the firing contraction curve and the amount of the final contraction vary with the ratio of the constituent clays. It was also found that the pot body, previously heated, follows the ordinary law of thermal expansion and contraction, until the temp. approaches that previously reached and then the change takes its characteristic course ; also that the heating curve of a pot body takes a cuspidal form at a temp. between 500° and 700°, and after being once burned at a very high temp., the complicated length change, which occurs below the temp., vanishes. The results obtained with clays and pot bodies which were heated at several constant temperatures ranging from 900° to 1,270° are very well expressed by the empirical formula : $x/(C-x) = A/(C-A) - Kt$ where x is the amount of contraction at time t, A

the initial length of the specimen, C the final contraction after heating infinitely long at a constant temperature, and K a constant. Experiments were carried out to determine the endothermal and exothermal reaction; the dehydration point of clay with a thermo-balance ; and the change of the microstructure of clay by heating. The conclusions are : (1) The dehydration of the constitutional water of kaolinite takes place between 400° and 600° ; (2) The dissociation of kaolinite into aluminium silicate and free silica commences very probably at 650° ; (3) The internal change takes place between 900° and 1,000°, and it is probably a polymerisation of the dissociated aluminium silicate ; (4). Between 1,200° and 1,300°, we have another internal change, which may be taken as the result of the recombination of free silica and aluminium silicate formerly dissociated at a lower temperature. Microstructure of stones. As the result of experimenting with bulb glass, stones have been classified into four kinds: (1) Unfused quartz grains coming from pot materials ; (2) ditto coming from glass batch ; (3) clay substance coming from pot materials and (4) insoluble foreign mineral coming from pot material as well as glass batch. 78 micro-photographs are given. S. Kondo.

SILLIMANITE DEVELOPMENT IN SOME TYPICAL CLAYS.—H. M. Kraner (*J. Amer. Cer. Soc.*, **7**, 726, 1924). The subject is first discussed from a theoretical standpoint. In microscopic methods of studying the development of sillimanite, the term "amorphous" has been used where "submicroscopic" would have been more satisfactory, since the results obtained by this method are entirely dependent upon the degree of magnification employed. The method of investigation consisted in tracing the development of sillimanite by observing the increase in the mean indices of refraction of the fired clay aggregates. Five typical American clays were used. The results indicated that (1) Decrease in the indices of refraction represents a change into the amorphous condition ; (2) The rapid increase in the indices of refraction between 600 and 1,000-1,100° is probably caused by the development of submicroscopic sillimanite ; (3) the decrease in the index of refraction above 1,200° of certain clays high in silica and fluxes is probably due to the re-solution of sillimanite, or to the passing into solution of the silica minerals, the effect of quartz being considerable. The failure of refractories at high temperatures is indirectly due to the development of sillimanite, which causes a segregation of the silica of the former clay molecule into the more impure portion (bond clay), resulting in increased fluidity. Sillimanite develops gradually, rather than suddenly ; it probably begins to form as soon as the clay molecule is dehydrated. Sillimanite development appears to take place as abundantly in pure clays as in those in which early fluidity operates to promote the size of the crystals. Kaolinite crystals show a negative elongation, whilst sillimanite has a positive elongation. Bowen and Greig's discovery that 3 $Al_2O_3.2SiO_2$ rather than $Al_2O_3.SiO_2$ is the only binary compound occurring in the Al_2O_3–SiO_2 system, though published subsequently, does not affect the conclusions drawn.

THE DEHYDRATION TEMPERATURE OF PYROPHYLLITE AND SERICITE.—J. L. Stuckey (*J. Amer. Cer. Soc.*, **7**, 735, 1924). Sericite is found in many clays, whilst pyrophyllite ($H_2Al_2Si_4O_{12}$), which closely resembles it optically, is present in some rocks and residual clays. Samples of pure pyrophyllite and sericite were heated to temperatures varying from 400° to 1,000°. Though the two minerals contain about the same amount of chemically combined water, it was found that, after 110°, there was no loss until between 300° and 400° in the case of sericite, and between 400° and 500° with pyrophyllite. At 800° sericite was completely dehydrated, whilst pyrophyllite still contained about 0·2%, which was driven off at 900°. Sericite lost much water between 500° and 600°, after which further loss was gradual and uniform. Pyrophyllite showed its greatest single loss between 600° and 700°. The results differ somewhat from those obtained by Le Chatelier.

ON SILICATES.—W. Eitel (*Ker. Rund.*, **32**, 569, 1924). A résumé of the work of Fenner, Shepherd and Rankin is given. With the aid of the Boeke

pressure furnace, the author examined the silicate-carbonate systems and succeeded in determining the stability relations of spurrite, $CaCO_3.2Ca_2SiO_4$, cancrinite, $3Na\,Al\,SiO_4.CaCO_3$, and carbonate meionite, $3Ca\,Al_2\,Si_2O_8.Ca\,CO_3$. Under pressures which retarded the dissociation of the carbonates, the phase diagrams appear extraordinarily simple, but when dissociation occurs, the free oxide brings about highly complicated reactions. It is remarkable that the carbonate-silicate melts react in the liquid phase without separation, and that, in contact with CO_2 above the critical point, they exhibit a fluidity otherwise unknown with silicates.

II. MANUFACTURING PROCESSES:

GENERAL.

THE MANUFACTURE OF AN INSULATING BRICK FROM DIATOMACEOUS EARTH.—C. A. Smith (*J. Amer. Ceram. Soc.*, **7**, 52, 1924). Mixtures of pulverised diatomaceous earth and clay in proportions of 5, 10, 15, 20, 30, and 50% of clay by weight were made up with 4 types of plastic clay, ground to pass an 80-mesh sieve. Dry-pressed briquettes were made, using 60% of water in the 0-5-10-15% clay mixtures, and 50% water in the 20-30-50% clay mixtures. Four trials of each body were fired to cones 06, 02, and 2. Thermal conductivity tests were made on the best bodies of the series. The results of the first and second choice bodies are :—

		Per cent. shrinkage	Per cent. absorption	Modulus lb. per sq. in.	Heat transfer value
First choice ..	Tenn. ball 20% Cone 06.	9·0	84·4	288	0·252
Second choice	Tenn. ball 20% Cone 02.	9·3	80·5	350·5	0·321
	Tenn. ball 25% Cone 06.	9·2	80·0	320	0·280

PATENTS.

IMPROVEMENTS IN THE MANUFACTURE OF REFRACTORY BRICKS, BLOCKS, OR THE LIKE FROM DOLOMITE OR OTHER MATERIALS POSSESSING PLASTICITY AT HIGH TEMPERATURE.—F. L. Duffield (*Brit. Pat.* 223,616, 21. Apr., 1923). Granulated dolomite, or other materials which become plastic at high temperatures, either alone, or mixed with fluxing agents, is moulded under pressure into bricks, blocks, etc., while in the plastic state, *i.e.*, at about 1,500°. The moulded articles are annealed slowly after emerging from the moulds. The articles may first be moulded in the ordinary way and subsequently remoulded under pressure on reaching the plastic stage.

THORIA CRUCIBLE PRODUCTION.—H. K. Richardson and T. M. Switz (*U.S. Pat.*, 1,512,801, 21. Oct., 1924). A slip for casting refractory ware consists of 40 parts of thorium oxide, 20 parts of grog, 5 parts of a double halide salt adapted to serve as a colloid, and 2 parts of a reagent capable of developing an electrolytic action in water. The slip is subjected to a vacuum to exhaust any gases therein.

COMPOUNDING AND PREPARATION OF BODIES, ETC.

PATENTS.

REFRACTORY MIXTURE.—G. Kallen (*Brit. Pat.* 221,852, 12 June, 1923). The mixture consists of zirconia, preferably in the form of crude zirconium ore, together with a number of binding agents, which soften progressively

as the temp. rises. The low melting-point binding agent may be pulverised glass, water glass or pulverised crystallised water glass, and, as high melting-point binding agents, compounds of magnesium, calcium, or aluminium (*e.g.*, pulverised dolomite, felspar, Portland cement, magnesite, clay, or bauxite) may be used. This material may be made up into tiles, bricks, crucibles, household utensils, etc., to which enamel linings may be applied. A refractory paint, suitable as a fire-proof coating on walls, roofs, etc., may be made by using a binding agent effective in the cold state, such as casein, tragacanth, agar, or platine. A protective layer of mortar or cement may be applied to such a fire-proof coating.

REFRACTORY BRICKS, ETC.—Stettiner Chamotte-Fabrik A. G. (*Pat. J.*, 1,856 1924). No. 21,897, June 12, 1924. The clay, with or without felspar, quartz, glimmer, etc., is first fired to a temp. above its melting-point (about 1,350-1,500°) and subsequently crushed, mixed with a binding clay, moulded and fired to about 1,200°.

PRODUCTION OF CLAY WARE.—Orqualin Ges. m.b.H. (*French Pat.* 572,475, 31 Oct., 1923). Clays containing insufficient SiO_2 to react with soluble fluorides are mixed in powdered form with quartz sand, the necessary quanitty of a sol. fluoride and enough water to render them workable. The ware which is fired to a comparatively low temp. has a firm, glaze-like coating. Red burning clays produce white ware with no black iron markings.

KILNS, OVENS, MUFFLES; FIRING TECHNIQUE, ETC.

THE BOOTH OPEN FIRE TUNNEL KILN.—(*Brick*, **65**, 680, 1924). The Booth tunnel kiln, operated by the Booth Brick and Lumber Co., of New Toronto, Ontario, is 335 ft. long, having a preheating zone 160 ft. long, a firing zone 100 ft. long and a cooling zone 75 ft. long. It is of the direct-fired type, but the ware is protected to a certain extent by bag walls. Fire enters the kiln through openings, controlled by dampers, in the bag walls. Shaker grates have been fitted. The kiln has a double crown, formed by a lower firebrick roof over which is built a second roof of common brick, the two crowns being 2 ft. apart throughout the length of the kiln. This flue supplies hot air to a dryer. Bituminous coal of good quality is used as fuel. There are six fire boxes on either side of the kiln. Stiff mud and dry pressed bricks are burned, 550 lb. of coal being required to dry and fire 1,000 bricks. The capacity is 25 to 30 thousand bricks daily. Firing temperature 1,037°.

REFRACTORIES FOR GAS RETORTS, WITH SPECIAL REFERENCE TO SILICA.—W. Emery (*Gas World*, **80**, 678, 1924; *Gas. J., Supplement*, 9 July, 1924). The advantages and disadvantages of silica materials (over 92% SiO_2) are discussed. Laboratory data (analyses, true and app. sp. gr., after expansion and contraction) relating to 14 refractories are given in tables. The thermal conductivity factor is discussed at some length. A number of horizontal and vertical retorts were examined after use, and the results are reported. Different methods of setting are illustrated. The microstructure of the materials is described by A. Scott in an appendix.

RETORTING AND REFRACTORY MATERIALS.—V. E. Harston (*Gas J.*, **166**, 530, 1924; *Gas World*, **80**, 444, 1924). A short historical sketch of the development of retorting is given. This is followed by a general account of refractories suitable for retorts, and of the best methods of construction.

THE "TURBINE" FURNACE.—(*Glass*, **1**, 117, 1924). An account is given of the progress made in steam jet forced draught furnaces.

TUNNEL KILN FIRING REFRACTORIES.—(*Chem. Met. Eng.*, **31**, 767, 1924). A tunnel kiln which has recently been put into operation by the Vitrefrax Co., is divided into the usual preheating, firing, and cooling zones. The first is about 33 ft. long, the second 25 ft., and the third 35 ft. The preheating zone presents no novel features.

The firing zone has seven burners on each side, each in a separate fire-box. This arrangement makes it possible to attain very high temperatures in the firing zone without intense local overheating. The cooling zone is almost a duplicate of the first zone. The kiln was designed to fire two classes of ware; one to a maturing temperature of cone 16, and the other cone 26.

BONDING HIGH-TEMPERATURE REFRACTORIES.—R. C. Gosreau (*Chem. Met. Eng.*, **31**, 696, 1924). The use of grain and powder refractories in electric furnaces is discussed. For high-temperature bonds, the silicates, the ferrates, and the aluminates are the best inorganic substances. Certain organic bonds, which burn out, leaving a film of carbon to hold together the particles of the refractory, should not be under-estimated. A number of binders (listed) were tested under conditions comparable to those prevailing in steel melting practice, the refractories employed being mainly electrically dead-burned magnesia, calcined magnesia, zircon, and zirconia, and certain mixtures of these. From the tabulated results, the following example may be taken as typical: Ten parts of 100-mesh zircon (79 per cent. ZrO_2,SiO_2) 88 parts 4 to 20-mesh magnesia, 2 parts 100-mesh silica were mixed to a stiff mud with magnesium chloride solution, (sp. gr. 1·225) the mixture being dried for 5 days at 110° and fired for 8 hours at 1,500° under reducing conditions. The resulting product was of a tan colour, had a very dense structure, with sharp, hard corners, and showed no evidence of fusion by FeO slag.

AUTOMATIC STOKING APPARATUS.—(*Allgem. Tonind. Ztg.*, **43**, 252, 1924). The apparatus has been constructed, and patented, by Max Liebscher, of Meissen. A fuel feeding unit is placed over each feed-hole in the series being fired. These units are carried (in fours, corresponding to one row of feed-holes), on a single, portable frame, on which is mounted a small electric motor, which supplies the necessary power. Each unit is adjustable in all directions on the frame, so that it can be made to fit on to the feed hole. By a simple coupling arrangement, one motor can be made to drive a number of units in addition to its own series; it is therefore not necessary that each frame should carry a motor. Each unit contains crushing mechanism, so that briquettes, or large pieces of coal can be fed into the hopper. After passing through the crushing mechanism, the coal collects in a small chamber holding 200 grams (about half a pound), which is closed automatically by a valve. This receptacle is filled in not less than two minutes. By moving a pointer, it can be made to discharge its contents into the kiln at regular intervals varying from two to fifteen minutes. Each unit is independent in this respect, in spite of a common drive. Cold air cannot possibly enter the kiln, even when the valve is open and the hopper completely empty.

THE OXIDATION OF CERAMIC WARES DURING FIRING.—V.—A QUANTITATIVE STUDY OF THE NATURE OF SULPHUR EVOLUTION IN KILN FIRING (PART II.).—F. G. Jackson (*J. Amer. Cer. Soc.*, **7**, 656, 1924). Tests were carried out on a round down-draught kiln burning fireclay, which contained sulphur and iron. The results are summarised as follows: (1) A considerable proportion of the volatile sulphur from the coal is absorbed by the ware until a temp. of about 760°, this absorption taking place in the following manner: (*a*) SO_2 is absorbed by surface moisture on the ware as H_2SO_3 up to 100°, after which H_2SO_3 is decomposed; (*b*) SO_3 is absorbed in the same way as H_2SO_4, which attacks the lime and iron. This absorption ceases at 100°, but the H_2SO_4 is not decomposed until about 260° is reached; (*c*) ferric sulphate is formed throughout the ware at temperatures up to 593° by the action of either absorbed acid solution or kiln gases on free ferric oxide; (*d*) sulphur is locked in the clay in an insoluble form, possibly as a sulpho-silicate, at all temperatures up to 704° under favourable conditions. (2) Sulphur is evolved from the kiln and passes away through the stack owing to (*a*) sulphur gases from the coal not absorbed by the ware; (*b*) SO_2 from H_2SO_3 at 100° and the breaking down of any sulphites formed;

(*c*) vaporisation and breaking down of H_2SO_4 at about 260°; (*d*) decomposition of pyrite and associated minerals, beginning at about 426°. This takes place vigorously; (*e*) decomposition of ferric sulphate, which gives off most of its gas between 560° and 775°; (*f*) decomposition of ferrous sulphosilicate probably beginning at about 704°. (3) Evolution of sulphur may be suspended temporarily by the ignition of carbon in the kiln. The carbon in pyrites, when burning, will retard the oxidation process. (4) Pyrites forms a central core in partly fired ware, but this core disappears on further firing; (5) A different core may be formed by too rapid firing, as when SO_2 and SO_3 are unable to escape from the centre when the surface has become dense. Ferrous silicate will then melt to a black mass at the centre, although the surface of the ware may be of proper colour.

SOME CONSIDERATIONS NECESSARY IN SELECTION OF REFRACTORIES FOR THE OPEN HEARTH.—S. Cornell (*J. Amer. Cer. Soc.*, **7**, 670, 1924). The kind, quality and quantity of refractory bricks used in steel plant furnaces, coke ovens, blast furnaces, open hearths and auxiliaries are discussed. The factors influencing the life of refractories in the open hearth furnace are dealt with, and details are given of furnace dimensions, etc.

OPERATING CONDITIONS IN THE OPEN HEARTH AS THEY AFFECT REFRACTORIES.—C. E. Williams (*J. Amer. Cer. Soc.*, **7**, 681, 1924). The factors which influence the life of the refractories, *e.g.*, corrosion, fusion of linings, abrasion and slag attack, spalling and breaking, etc., are briefly discussed, mainly with reference to basic open hearth practice.

SILICEOUS MATERIAL IN THE GAS AND COKE INDUSTRIES.—G. Bia (*Gas World*, **81**, 19, *Coking Sect.*, Nov. 1st, 1924). The relative advantages and disadvantages of siliceous and aluminous material are discussed. Quartz or sand should be converted as far as possible into tridymite. The best raw material for this purpose is a tertiary quartzite found in various parts of Europe, but not in France, Great Britain, or N. America.

THE DESIGN OF KILNS AND FURNACES FROM MODEL TESTS.—F. H. Norton (*J. Amer. Cer. Soc.*, **7**, 783, 1923). A method is described by which small models of kilns may be used in estimating the efficiency of the full-sized structure, as is done in engineering practice, with consequent economy of time and money. The theory is discussed in detail. By the aid of model tests, it is possible to predict with considerable accuracy:—The pressures and velocities throughout the kiln and flues; the distribution of temperature in the kiln at any stage; the heat lost in the stack and through the walls; the amount of fuel required to fire to a given temperature; the time required to reach a given temperature.

DETERMINATION OF THE DISTRIBUTION OF HEAT IN KILNS FIRING CLAY WARE.—W. E. Rice and R. A. Sherman (*J. Amer. Cer. Soc.*, **7**, 738, 1924). The methods of collecting data, from which the distribution of the heat input could be determined, the calculation of the heat accounts, and a discussion of the various items are presented in detail. The heat accounts are given under 14 items. Seven kilns firing refractory materials were examined. Short methods of determining approximate kiln efficiency and the more important heat losses are indicated. The methods presented are intended to serve as a foundation for the formulation of a code for testing kilns.

Patents.

BURNING MATERIALS IN TWO OR MORE STAGES.—G. Polysius (*Ger. Pat.* 400,815, 2 Dec., 1922). The preheating and calcination of cement, magnesite, etc., is effected with low-grade fuel, whilst for the sintering process one or more electric arcs, or hot air or gases which have been passed over two or more such arcs, are employed. Each method of heating is specially adapted to its particular purpose, so that the process functions very economically.

HEAT INSULATING MATERIAL.—P. de Angelis (*Brit. Pat.*, 210,459, 28 Jan., 1914). Silicate cotton (mineral wool, slagwool), is treated with sodium or potassium silicate of 1·357—1·384 sp. gr. and mixed with an equal quantity of a solution of marine lichen of the same density. The product is light, supple and elastic, allowing great ease of manipulation.

TUNNEL KILN.—C. Dressler (*U.S. Pat.* 1,509,195, 23. Sept. 1924). Means are provided approximately at the centre of the main heating chamber for developing a high temperature therein. Gas propelling mechanism within the kiln is adapted to equalise the distribution of heat in the forward heating zone.

TREATMENT OF GASES CONTAINING DUST AND FUMES.—F. W. Huber (*U.S. Pat.* 1,508,331, 9 Sept., 1924). After having been subjected to high potential electrical discharge, cement kiln gases containing potassiferous material are de-electrified by being passed through interstitial spaces containing dry electrically conductive material.

GLAZES, ENAMELS.

THE CHICAGO VITREOUS ENAMEL PRODUCT CO.—(*Cer. Ind.*, **2**, 353, 1924). A well illustrated account is given of the plant and methods. A rotary sprayer is installed which is capable of turning out two completed pieces of ware, up to 8 sq. ft. in size, every 10 to 15 seconds.

SUGGESTIONS FOR DEVELOPMENT IN ENAMELLING TECHNOLOGY.—H. F. Staley (*J. Amer. Cer. Soc.*, **7**, 719, 1924). The suggestions include : The more general use of the system of representing enamel formulæ in percentage amounts of melted materials in order to enable the percentage of each oxide in the finished enamel to be calculated ; further study of the factor of coefficient of expansion ; improvements in mechanical strength, resistance to thermal shock, etc.; widening the heat range for ground coat enamels by the addition of substances which render the enamel more fluid at low temperatures ; greater control of the felspar variation by accurate analysis of each shipment, or by substituting silica as the chief refractory in the enamel.

THE PLASTIC PROPERTIES OF ENAMEL SLIP.—R. D. Cooke (*J. Amer. Cer. Soc.*, **7**, 651, 1924). The apparatus employed was a modification of the Bingham plastometer, rendered applicable to enamel slips. The theory of plasticity is discussed briefly, reference being made to Bingham's work. The results, shown graphically, indicate that a rise in temperature increased the mobility without changing the elastic limit, or yield value; increasing the water content increased the mobility and reduced the yield value ; increasing the clay content raised the yield value without affecting the mobility ; and addition of magnesium sulphate has a similar effect. Sodium chloride, sodium carbonate, sodium acetate, sodium thiosulphate, ammonium chloride and amm. carbonate increased the yield value slightly, whilst borax, acetic acid, aluminium chloride and cobalt nitrate increased the yield value considerably. Magnesium sulphate, barium chloride and calcium chloride increased the yield value enormously and reduced the mobility. Sodium silicate reduced the yield value to zero and decreased the mobility.

ENAMELLED WATCH-DIAL.—Shizuo Shimomura (*J. Jap. Assoc.*, **32**, 93, 1924). The cubical coefficient of expansion must be about 300×10^{-7} and 280×10^{-7} and the most desirable melting points about 750° and 800° for ground-coat and cover-coat frits respectively. Clay, felspar, boric acid and borax are not used as raw materials for the cover-coat frit. Arsenious acid is the only opacifier which gives good results. No. 1 in the following table, prepared from an excellent Swiss cover-coat enamel, gave a transparent glass which could not be opacified by further increase of arsenious acid. A reduction of the alkalies made the glass opaque but it became too refractory.

By increasing the lead oxide, light opaque glasses were obtained. They were then improved further by adding more arsenious acid, although it made the enamels too brittle. This defect was overcome by changing the amounts and the ratio of the alkalies. Thus a fairly good enamel, No. 11, was obtained.

TABLE I. COVER-COAT ENAMELS.

	Quartzite	Red lead	Arsenious acid	Potassium carbonate	Sodium carbonate	Nitre
No. 1	100	120	13	36	45	5
No. 11	100	170	16	22	3	4
No. 14	100	163	17	45	3	4
No. 17	100	160	19	24	5	4

Experiments on the ground-coat frits for No. 11 are described. A batch, composed of quartzite 100, red lead 140, felspar 70, slaked lime 25, antimony oxide 15, sodium carbonate 50 and nitre 10, gave a satisfactory result. The use of fluorspar was abandoned, as it caused bubbling. The introduction of boric acid seemed to make the enamels too hard. Experiments on the further improvement of enamel No. 11 showed that an increase of potash in one enamel, at the expense of lead oxide, made it more bright and fit for charcoal pressing on account of its softness. Enamel No. 14, for instance, is far better than No. 11. Further decrease in lead oxide made the enamel too soft, though better results in the charcoal pressing were obtained. This defect was overcome by replacing some potash with soda. Enamel No. 17 is one of such compounds. A ground-coat frit containing quartzite 100, red lead 155, felspar 70, slaked lime 25, stannic oxide 50 (or stannic oxide 25+ arsenious acid 25), sodium carbonate 52 and nitre 10 was excellent for use with these cover coats. Cover-coat frits must be air-cooled and then ground to pass through a 120-sieve. They are then washed with water and nitric acid. They are used as cover-coat enamel as they are. Ground-coat frits may be poured into water. A ground-coat enamel is made by regrinding a mixture of ground-coat frit and a cover-coat enamel, say in equal parts. The ground-coat was fired for 4 minutes at 750°., while the cover-coat was heated for about 15 minutes at 850°. S. KONDO.

PLANT AND MACHINERY, ETC.

A NEW BRICK PRESS.—(*Tonind. Ztg.*, **48**, 947, 1924). The external appearance of this machine differs entirely from previous types, no moving parts, with the exception of the belt pulley, being visible at all. All wheels, bearings, shafts, etc., are enclosed in a cast iron cylinder with a removeable lid, the casing being completely dust proof and oil tight. The wheels and shafts are made of steel. The wheels have planed teeth and run in oil baths, so that the machine runs smoothly and almost noiselessly. The shafts run on strong, specially constructed roller bearings. The worm and its casing are made of special steel and their design is based on many years experience. The feed roller is also cased in and is closed by means of an adjustable scraper, so that there is no extrusion of clay. The machine has a high gearing ratio, and can, therefore, be driven direct from an electric motor, but any form of transmission is equally suitable. This gearing arrangement permits the use of ordinary light belts, thus eliminating troublesome belt repairs. Furthermore, the belt is not subjected to the usual wear and tear of throwing in and out, since the driving pulley is constructed to act as a friction clutch, which can be regulated to give against excessive resistance.

PATENTS.

A GLASS DIE FOR BRICK AND TILE MACHINES.—Deyerlein (*Südd. Tonind.*, **6**, 614, 1924; *Swiss Pat.* 106,953. E. Schmid, 16 Sept, 1924). With the object of reducing the friction between the die of a brick machine and the sandy material, contained in the clay, a mouthpiece consisting of a metal casing enclosing and protecting a glass die has been introduced so that the extruded column of clay comes into contact with glass only. This mouthpiece can be fitted to any brick or tile machine. The glass die, which is of conical form, has a flange at the wide end. When the mouthpiece is fitted to the machine, the clay passes through the opening surrounded by the flange and presses the glass die firmly into the metal casing. This casing, which is in two parts, has two projections, through which bolts are passed to hold the two halves together. A sheet of leather or asbestos should preferably be placed between the two halves. The casing is attached to the machine by means of a flange. Two ribs are provided above and below the aperture, so that, when not in use, the mouthpiece will stand firmly on the ribs and the projections, thus protecting the glass from breakage. The glass die offers much greater resistance to friction than a metal die of similar construction. Furthermore, it is easily interchangeable, so that the metal casing can be used for any number of dies.

III.—FINISHED PRODUCTS: TESTING, ETC.

REPORT ON LOW TEMPERATURE HEAT INSULATORS.—E. Griffiths (*Food Investigation Board Special Report* No. 5, October, 1924). The insulating properties of the materials commonly used for cold storage construction were investigated. The apparatus employed consisted essentially of a central hot plate, having a "guard ring." This plate, which was heated electrically, was fixed contrally between two cold plates, and the material under test was packed between, the apparatus being symmetrical about the hot plate. The heat transmitted was measured in terms of the watts dissipated in the hot plate, and the temperature difference was obtained by means of a number of thermocouples at various points on the hot and cold faces. The tests showed that convection currents occurred in the granular material resulting in the top panel of the guard ring becoming hotter than the bottom. The presence of horizontal baffles did not improve the insulation of a wall, since complete circulation of air took place in each compartment formed by the baffles. Thermal conductivity values were obtained for various forms of cork, slag-wool, charcoal, diatomaceous earth, three forms of rubber packing, pitch pine, facing cement, bitumen composition, concrete blocks, etc., ; the results are given in C.G.S. units and in B.Th.U. The temperature range employed varied considerably between –15° and 115°. Dry cork, slag-wool, charcoal, and wood fibres were found to have practically the same thermal conductivity, viz., 0·00011 C.G.S., diatomaceous brick, 0·000223, magnesium oxychloride cement, 0·00038, and concrete blocks 0·0028. The special form of calorimeter, designed to determine the specific heat of the light and bulky materials tested, is described in an appendix. The results obtained on five materials are tabulated.

HIGH TEMPERATURE LOAD AND FUSION TESTS OF FIREBRICKS FROM THE PACIFIC NORTHWEST IN COMPARISON WITH OTHER WELL-KNOWN FIREBRICKS.—H. Wilson (*J. Amer. Cer. Soc.*, **7**, 34, 1924). Seventeen samples of fireclay bricks from the Pacific Northwest were tested and compared with 27 other commercial brands of various types. The high temp. load test showed that these bricks were of good quality, some being classed with the best fireclay brick, and one with the best diaspore bricks. A method is suggested for testing super-refractories under load at high temperatures. This is similar to the standard test, but the temperatures are measured by cones, and are raised until 10% linear deformation of the brick occurs. The data obtained from the cone fusion tests are used in the

application of the heat. A numerical value, expressing the area under the cone-shrinkage curve, affords an easy method of comparing the high temperature load resistance of various refractories. Best results were obtained with bricks composed of crystalline materials which had developed a recrystallised bond of the same composition.

THE ELECTRICAL RESISTIVITY OF REFRACTORIES.—A. V. Henry (*J. Amer. Cer. Soc.*, **7**, 764, 1924). The method employed followed, in general, that developed by Northrup for the determination of the resistivity of refractories up to 1,600°. Tests were made on flint fireclay, kaolin, sillimanite, silica, magnesite, three types of talc and diaspore. The refractories were made up into small tiles, which were clamped between graphite plates. This testing unit was suspended in a tube furnace, the temperature of which was carefully controlled by a rheostat. Electrical resistance measurements were made with a Wheatstone bridge, and temperature measurements with a platinum platinum-rhodium thermocouple, readings being taken up to 1,500°.

Of the materials tested, magnesite has the highest resistance at low temperatures, but at high temperatures it falls almost to that of flint fireclay, which has the lowest resistivity at all temperatures, due to its high percentage of fluxes. The kaolin curve lies parallel to that of flint fireclay. Diaspore has a higher resistivity than kaolin. The resistivity curve for sillimanite is of the same general nature, but higher than those for fireclay, kaolin, and diaspore. The silica curve is parallel to that of sillimanite and crosses that of magnesite at 1,325°. Indian, Maryland, and Italian talcs have high resistivities. With the exception of magnesite, the rate of increase in resistivity decreases with a rise in temperature. The resistivity of a complex ceramic body, especially if open and porous, is not constant for a given temperature above that at which its most fusible mixture melts. Resistivity decreases with an increase in impurities ; in the case of Italian talc, it depended not only upon the amount, but also upon the distribution of the impurities present. Assuming good electrical contact between electrodes and test piece, resistivity is independent of the potential applied. The tests were all carried out under reducing conditions, in an atmosphere of nitrogen.

CONSTITUTION AND MICROSTRUCTURE OF SILICA BRICKS AND GROG BLOCKS USED IN TANK FURNACES.—Zenziro Uneno. (Report of the Research Laboratory of the Asahi Glass Co., No. 10, 67 pp., 1923). Descriptions of the microstructure of typical American ganister-quartzites as well as silica bricks made in America and Belgium are given. Quartzites of Manchuria and Korea. The chief kind of Dairen quartzite is bluish grey to greyish white in colour and has a glassy appearance. It consists of quartz grains 0·4–0·6 mm. in diameter, which are cemented together by secondary quartz-grains under 0·05 mm. in diameter. White granular quartzite of the same district is more crushable and very suitable for the manufacture of silica bricks. Under the microscope, the coarse grains are 0·6–0·4 mm. in diameter and round in shape. In the reddish brown quartzite of Ryutozan, Ryojun, grains about 0·5 mm. in size are cemented by secondary quartz, about 0·03 mm. in diameter, and red limonite. Its refractoriness is cone 32-33, while that of the Dairen quartzite is cone 33–34. Sandstone of Chinkaiwan, Korea, chiefly consists of round grains, 0·3–0·1 mm. in diameter, and is used only as mortar material, since it is too weak. The chief quartzite producing districts of Japan are Watsukamura, in Yamashiro, Bungo, Tamba ,Tango, Tosa, Awa and Iyo. Thin sections of white Watsuka quartzite show no cementing matter ; it consists solely of angular quartz-grains, which are 0·8–0·2 mm. in dia., and exhibit undulatory extinction. The grains easily come off in firing. Bungo quartzite of superior quality is a red rock, finely veined with white quartz. The red portion is a mixture of very minute grains of quartz and tuff ; the white veins consist of quartz grains, 0·5–0·05 mm. in diameter. An analysis of the quartzite gives: Silica 95·19, alumina 1·03, ferric oxide 3·13, lime trace, and magnesia trace. The inferior kind of Bungo quartzite is entirely or mainly composed

of coarse quartz grains, varying from 2·0 to 0·6 mm. in size. Quartzites of Tamba, Tango, Tosa, Awa and Iyo resemble those of Bungo. The microstructure of domestic silica bricks, which had been used in a tank furnace was studied. The outer portion of an 18″ wall between ports, which had been in use for three years, was compared with other portions with respect to chemical, physical and optical properties.

Samples	Silica	Alumina	Ferric Oxide	Lime	Magnesia	Alkalies
0–5″ from outside	94·87	1·90	1·60	1·31	0·13	0·19
0–1″ from inside	94·02	1·97	2·00	1·20	0·02	0·79

Thin sections of the portion 1″ to 3″ from the inside, rarely showed wedge-shaped twins of tridymite. The portion 0 to 1″ from the inside contained the wedge-shaped twins and lath-like crystals of tridymite. Thin sections prepared from the surface of an arch-brick in a port, which had been exposed to the highest temperature in the furnace, were composed of polysynthetic twins of cristobalite, 0·50 mm. long and 0·25 mm. wide, and fork-like crystals of tridymite. Grog tank-blocks. The chemical composition, size of grains, and microstructure of foreign tank blocks are described. A detailed description of the raw materials, manufacture, chemical composition and microstructure of tank blocks made by the Asahi Glass Company are given. Longitudinal sections of such blocks made by the Asahi Glass Co., which had been used in the flux-line of a tank-furnace, exhibited six continuous layers as follows :—

	Outmost layer	Second layer	Third layer	Fourth layer	Fifth layer	Inmost layer
Colours	Light reddish brown	Yellowish brown	Brownish grey-black	Blackish grey	White	Brown (transparent)
Ig. loss	0·27	0·21	0·27	0·22	0·27	0
Silica	61·94	61·78	63·96	63·76	65·34	58·10
Alumina	32·82	33·00	32·41	31·63	30·29	28·74
Ferric oxide	2·55	2·74	1·96	1·74	1·32	1·59
Lime	1·11	0·70	0·72	1·39	0·73	1·04
Magnesia	0·36	0·66	0·38	0·51	0·43	0·49
Alkalies	0·94	0·91	0·30	0·75	1·63	10·04

Thin sections of the second layer indicated some evidence of slight softening in the block. Those of the third layer contained numerous crystals of sillimanite, 0·04 mm. long. The crystals grew up to 0·1 mm. in the fourth layer. Thin sections of the fifth layer were full of sillimanite and glass, though some quartz grains were still observed. The largest crystals of sillimanite measured 0·85 mm. in length. Some quartz grains had wedge-shaped twins of tridymite in their centres. The inmost layer was nothing but a glass. S. Kondo.

PHYSICAL CHARACTERISTICS OF SPECIALISED REFRACTORIES, V. THERMAL CONDUCTIVITY OF CARBORUNDUM REFRACTORIES.—M. L. Hartmann and O. B. Westmont (*Trans. Amer. Electrochem. Soc.*, **46**, 287, 1924, Preprint No. 21). The method employed was that introduced by Boyd Dudley, modified to the extent of an additional guard ring to prevent lateral flow of heat for temperatures up to 1,400°. (The highest temperatures obtained by Dudley did not exceed 1,000°.). Special precautions were taken to ensure a high degree of accuracy in the calorimetric readings. Conductivity data were obtained on furnace walls as commonly constructed, measurements being made on 7 carborundum single walls and on 8 carborundum—fireclay composite walls. The thermal conductivity of practically pure carborundum was found to be constant for temperatures between 650 and 1,350°, whilst with ceramically bonded carborundum it increased with rising temperature. The temperature gradient through a carborundum wall increases with increasing percentages of fireclay bond in the bricks. Contrary to the results obtained by other investigators (*cf.* A. T. Green, TRANS., **21**, 394, 1922 ; *Gas J.*, 1924, **167**, Refractory Materials Supplement, July 9th, 31), the authors state that the thermal conductivity of fireclay is approximately inversely proportional to the porosity. Insulation of carborundum walls produced a marked decrease in the conductivity, and it is concluded that, for any given temperature, the thermal conductivity of carborundum increases as the amount of heat energy transmitted is increased. In the case of fireclay, however, it is practically independent of this factor. The fall in temperature due to the gas film resistance at the hot surface of insulated furnace walls was approximately 80°, and that due to the joint in composite walls was 30°. The coefficients of thermal conductivity and the heat flow through various types of walls—with a temperature of 1,500° in the combustion chamber—are given in tables.

V.—GLASS: GENERAL.

SURVEY OF THE DURABILITY OF ALKALI-LIME GLASSES.—G. Keppeler (*Sprech.*, **57**, 617, 1924). Recent data on the durability of alkali-lime glasses are collected and arranged, the object being to indicate the possibility of grouping these glasses with some degree of accuracy into hydrolytic classes (after Mylius) on the basis of their composition.

COLOURED GLASSES IN HOLLOW GLASS MAKING.—C. Duvivier (*Verre*, **4**, 197, 1924). Methods of producing coloured glasses simply and inexpensively are outlined.

THE CAUSE OF TURBIDITY IN GLASS.—M. von. Reiboldt (*Sprech.*, **57**, 645, 1924). Turbidity in glass may be due to the treatment during melting and firing, to the firing process, or to exterior influences. The latter are discussed with reference to certain experiences in different parts of the world. The article does not deal with such factors at incorrect compounding, faulty preparation and mixing of the batch, etc.

NOTES ON THE SODA-LIME-SILICA DIAGRAMS.—E. Zschimmer (*Sprech.*, **57**, 466, 1924). A discussion of the paper by F. Gelstharp and J. C. Parkinson (*Trans. Amer. Cer. Soc.*, **16**, 109, 1914).

RAW MATERIALS USED IN THE MANUFACTURE OF GLASS.—C. J. Peddle (*Glass*, **1**, 532, 1924). The various factors involved in the production of opal glass are discussed.

SOME COMBUSTION PROBLEMS IN GLASS MAKING.—C. D. Smith.—(*Glass*, **1**, 543, 1924).

THE ANNEALING AND RE-ANNEALING OF GLASS.—W. M. Hampton (*Glass*, **1**, 547, 1924). The factors involved in the annealing of glass are discussed. Relations connecting the strains present when cooling commences, strain due to gradient, and strain present after cooling are obtained and the

equations are applied to the case of slabs. Tables showing the proportion of temporary strain remaining as permanent strain for different kinds and sizes of slabs are given. Considerations affecting the annealing temperature and the conditions for minimum total annealing and cooling times are dealt with. Errors in pyrometry receive attention. Data relating to the annealing of various kinds of glass are tabulated.

MARBLE GLASS FOR ELECTRIC LIGHT SHADES.—(*Diamant*, **46**, 382, 1924). A new method of reproducing marble effects (*Ger. Pat.* 374,414), consists of coating the inside of a glass article with a thin paste made up of 9 parts of powdered Geyserite from the Taunus (99·8 SiO_2) and one part of waterglass. The article is dried at 40° to 50° in a drying chamber. To produce the marble effect, colouring matter is added, either before or after the first drying, the article being shaken about to distribute the colour. After the first drying, a second coating of the same mixture in a thicker form, *i.e.*, containing less waterglass, is applied. The waterglass merely serves the purpose of binder, the water being all driven off during drying. The crystalline nature of the Geyserite produces a very pleasing effect.

GLASS DECORATION WITHOUT FIRING.—(*Diamant*, **46**, 298, 1924). A process of applying coloured designs to glass by means of a substance sold under the trade name of "Adhesin" is described. The decorated articles are placed for about half an hour in a chamber and maintained at a temperature of 120-200°.

PLATINISING GLASS.—(*Diamant*, **46**, 298, 1924). Platinum chloride is mixed with lavender oil and made up into a homogeneous mass with a flux, consisting of lavender oil, lead borate and lead oxide. This paste is applied to one side of the glass with a soft brush. When dry, the glass is fired to a low temp. (red heat), in a muffle.

NEW METHODS OF DECORATING GLASS.—(*Diamant*, **46**, 316, 1924). The reverse side of a sheet of glass is first coated with a layer of an oil colour, to which is applied the albumin bichromate film. This is then exposed, whereupon the gelatine bichromate film is applied, and developed in the usual way. The excess oil colour is then removed by a suitable solvent. By this means, the coloured positive appears on the front side of the sheet. Polychromatic decorations can be applied by this method.

DESIGN OF A 14-POT RECUPERATIVE GLASS FURNACE.—E. W. Koering (*Glass Ind.*, **5**, 105, 1924). A common method of designing a recuperative glass furnace is presented, from data collected from various sources.

FACTORS AFFECTING THE LIFE OF A TANK.—F. C. Flint (*Glass Ind.*, **5**, 183, 1924). A general discussion (by various manufacturers and users) of the proposal of W. K. Brownlee to decrease block corrosion, and conserve fuel, by insulating glass tanks.

PAINTING ON MATT GLASS.—(*Diamant*, **46**, 128, 1924). A few technical hints are given.

A GOOD CORROSIVE FOR GLASS.—(*Diamant*, **46**, 206, 1924). A soft, uniform matt surface is produced on sheet glass by dipping in a mixture of equal parts of ammonium fluoride solution and conc. hydrofluoric acid, to which a small amount of potassium fluoride is added.

MOULDS AND MOULD DESIGN.—A. V. Hussey and S. Coles (*Glass*, **1**, 447, 1924). The design of moulds is studied with the object of determining the most suitable proportions of the various parts in relation to their influence on the formation of the finished blank.

OPERATING GLASS TANKS.—B. Schieldrop (*Glass*, **1**, 451, 1924). A method of taking heat balances to check operations in a glass tank furnace is advocated and described.

MATERIALS FOR COLOURED GLASSES.—C. J. Peddle (*Glass*, **1**, 484, 1924).

THE FORD PROCESS FOR THE CONTINUOUS PRODUCTION OF PLATE GLASS.—C. Saxton (*Glass*, **1**, 493, 1924).

THE PRODUCTION OF HIGH-GRADE COLOURLESS GLASS IN TANK FURNACES.—G. O. Smith (*Glass Ind.*, **5**, 1, 1924).

THE USE OF SELENIUM AS A DECOLORISER.—R. R. Shively (*Glass, Ind.*, **5**, 26, 1924).

THE UMBRASCOPE.—C. D. Spencer and A. E. Badger (*Glass Ind.*, **5**, 119, 1924). The umbrascope is a simple instrument for the determination of surface irregularities of transparent, thin-walled glass objects. It consists essentially of an illuminator (concentrated filament lamp), and a simple lens by which an image of the filament is focussed on a vertical slit in a small screen. The article to be examined is placed between this screen and a short distance from a ground glass screen, upon which the image of the object is thrown.

U.S. GOVERNMENT SPECIFICATIONS FOR FLAT GLASS FOR GLAZING PURPOSES.—(*Glass Ind.*, **5**, 129, 1924).

RAW MATERIALS USED IN THE MANUFACTURE OF GLASS.—C. J. Peddle (*Glass*, **1**, 436, 1924). A résumé of the literature relating to compounds containing aluminium is given.

REFRACTORY MATERIALS FOR GLASS WORKS.—A. B. Searle (*Glass*, **1**, 443, 1924). A résumé of the requirements of refractories for glass furnaces is given.

THE COLOURED GLASS IN MEDIÆVAL WINDOWS.—J. A. Knowles (*Glass*, **1**, 201, 1924). All coloured glass used in mediæval times was imported into England.

ANCIENT PAINTED GLASS IN LONDON.—F. S. Eden (*Glass*, **1**, 248, 1924).

EUROPE'S MOST MODERN SHEET GLASS FACTORY.—(*Glass*, **1**, 253, 1924). An illustrated account is given of the Libby-Owens plant in Belgium.

RAW MATERIALS USED IN THE MANUFACTURE OF GLASS.—C. J. Peddle (*Glass*, **1**, 340, 1924). Potassium carbonate is discussed. The oxides of sodium and potassium, as fluxes for glass, are compared. Methods of manufacture are outlined.

ENGLISH HAND-MADE CRYSTAL.—C. Saxton (*Glass*, **1**, 347, 1924). The methods of manufacture and of decoration are described and illustrated.

MACHINE-DRAWN GLASS TUBING.—(*Glass*, **1**, 111, 1924). A discription of the Wembley works of the G.E.C. The pots are made on the works of Stourbridge clays. The average life of the pot is 21½ weeks.

RAW MATERIALS FOR THE GLASS INDUSTRY.—C. J. Peddle (*Glass*, **1**, 148, 1924). Limestone, lime, etc., are dealt with.

XVII. CENTURY WINEGLASSES.—F. Buckley (*Glass*, **1**, 153, 1924). An illustrated account is given of the development of the industry.

STAINED GLASS AT CALDEY.—Dom Theodore (*Glass*, **1**, 155, 1924).

THE MANUFACTURE OF SHEET GLASS.—(*Glass*, **1**, 161, 1924). The principles of the Fourcault process are outlined.

RAW MATERIALS USED IN THE MANUFACTURE OF GLASS.—C. J. Peddle (*Glass*, **1**, 196, 1924). The preparation, properties, etc., of soda ash are discussed.

THE GLASS WORKS AT CHINWANGTAO.—(*Verre*, **4**, 173, 1924). The works were founded by a group of Belgian and Chinese financiers, for the manufacture of plate glass by the Fourcault process.

FINE GLASS MANUFACTURE.—J. H. Gardiner (*Chem. News*, **128**, 177, 1924). A broad outline of the art of glass making is given. The manufacture of thermometer tubing is dealt with at greater length.

MODERN BOTTLE GLASS WORKS.—R. Schneider (*Glashütte*, **54**, 136, 1924). A long article dealing with the whole subject in detail.

THE RE-CALCULATION OF BATCH INGREDIENTS.—H. Kühl (*Glashütte*, **54**, 325, 365, 384, 1924). A table is given showing the molecular equivalents of batch ingredients.

THE RÔLE OF THE RAW MATERIALS IN THE MANUFACTURE OF SEMI-CRYSTAL.—C. Duvivier (*Verre*, **4**, 169, 1924).

COLOURING GLASSES WITH COPPER, I.—Kitsuzo Fuwa (*J. Jap. Cer. Assoc.*, **32**, 138, 1924). The colouring action of copper and its compounds on glasses with the formula: $R'_2O.3SiO_2$, $R'_2O{\cdot}R''O.3SiO_2$, $R'_2O{\cdot}0{\cdot}5B_2O_3.3SiO_2$, $R'_2O.R''O\ 0{\cdot}5B_2O_3.3SiO_2$, $1{\cdot}3R'_2O.R''O.6SiO_2$ or $R'_2O.B_2O_3.6SiO_2$ is reported. One per cent. of CuO produced colours varying from light blue to dark indigo. In general, soda glasses were coloured darker than potash ones. Boron, barium or lead, intensified the colour. Boric acid encouraged the development of green. The effect of reheating glasses coloured with 1–3% CuO is described. The potash borosilicate glass was covered with a thin, ruby-red layer. Colours given by 1% of Cu_2O varied from light to dark blues with the exception of $K_2O.CaO.3SiO_2$, $K_2O.ZnO.0{\cdot}5B_2O_3.3SiO_2$ and $1{\cdot}3K_2O.ZnO.6SiO_2$, which were colourless, light purplish blue and light yellowish brown respectively. One per cent. of metallic copper imparted to most of the glasses colours varying from almost colourless to dark blue, while $R'_2O.CaO.3SiO_2$, $K_2O.ZnO.3SiO_2$ and $R'_2O.BaO, 0{\cdot}5B_2O_3.3SiO_2$ were coloured yellowish brown, light yellow and greenish brown respectively. Generally speaking, the colouring action of metallic copper is weaker than that of Cu_2O. 2·15% of cupric chloride gave blues or greenish blues of varying intensities, except $K_2O.CaO.2SiO_2$ and $K_2O.ZnO.3SiO_2$, which were coloured light and dark brown respectively. 1·25% of cuprous chloride coloured $Na_2O.BaO.3SiO_2$, $Na_2O.ZnO.0{\cdot}5B_2O_3.3SiO_2$ and $K_2O.CaO.0{\cdot}5B_2O_3.3SiO_2$ dark brown, light yellow and brown respectively, the other glasses being coloured blue. 3·15% of the sulphate ($CuSO_4.5H_2O$) imparted blues or indigo blues to most of the glasses, though $Na_2O.ZnO.3SiO_2$ was brown and $K_2O.BaO.2SiO_2$ a dark blackish brown. All batches containing lead produced a dark blue alabaster, probably owing to the formation of lead sulphate. 3·75% of the nitrate ($Cu(NO_3)_2{\cdot}6aq$), produced blue, dark blue or indigo blue in all glasses. The blue coloration is even stronger than that with CuO. 1·4% of Malachite green produced opaque vermillion in $Na_2O.CaO.3SiO_2$ and opaque dark brown in $K_2O.CaO.3SiO_2$, while it gave various blues to other glasses. 2·52% of the acetate ($Cu(C_2H_3O_2)_2{\cdot}aq.$) gave a light yellow, yellowish green, yellowish, reddish or greenish brown colour to the glasses, with the exception of $Na_2O.CaO.3SiO_2$ and $Na_2O.PbO.3SiO_2$, which were coloured blue. S. Kondo.

COLOURING GLASSES WITH COPPER, II.—Kitsuzo Fuwa. (*J. Jap. Cer. Assoc.*, **32**, 167, 1924). The effect of oxidising agents on colours produced by copper and its salts was studied. The full colouring power of 1% CuO was developed in batches containing the same amount of nitre, while 1–2% of nitre were required to produce the deepest blue with 1% of Cu_2O or metallic copper. 1–4% of the oxidising agent was added to those batches which had produced colourless glasses or glasses with colours other than blue in the experiments described in the first report. Batches with cupric chloride required 1–2% of the oxidising agent to produce a blue. Those with cuprous chloride, copper sulphate or basic carbonate gave blue glasses with 1% of nitre. Batches with copper acetate required 1–4% for the same purpose. Generally speaking, potash glasses seem to consume more nitre than soda glasses. In an experiment with batches containing 1% of cupric oxide

after melting, 0·5% of potassium tartrate produced a red in $Na_2O.CaO.3SiO_2$ or $K_2O.ZnO.3SiO_2$, a light pink in $Na_2O.BaO.3SiO_2$ and a reddish brown in $1{\cdot}3Na_2O.CaO.6SiO_2$, whilst 0·5-5·0% produced blues or browns in the other glasses. Nodules of copper or lead were often found on the bottom of the pots. The addition of 0·5% of the reducing agent together with 1·0% of cuprous oxide resulted in the production of a brown glass in most cases, though a few glasses were coloured light blue. The proportion of a copper salt in a batch was such that its oxide corresponded to 1% of the glass. Only 0·5% of the reducing agent revealed marked changes in the colour of $R'_2O.R''O.3SiO_2$; *e.g.*, $K_2O.CaO.3SiO_2$ and $Na_2O.BaO.3SiO_2$ gave a dark red glass. The effect was much more gradual in borosilicate glasses. The composition of the glasses exhibited a marked influence on the action of the reducing agent, and the influence of R''O seems to be stronger than that of R'_2O. With copper sulphate $R'_2O.R''O.3SiO_2$ glasses were coloured brown by 1–2% of the reducing agent, whilst boro-silicate glasses required 5%. Copper nitrate consumed much more reducing agent than other salts in melting. With basic copper carbonate, brown opaque glasses were obtained with 1–5% of the reducing agent. S. KONDO.

COLOURING GLASSES WITH COPPER, III. Kitsuzo Fuwa (*J. Jap. Cer. Assoc.*, **32,** 204, 1924). The effect of arsenious acid on colours produced by copper, its oxides, and salts was studied. Cupric oxide. Arsenious acid produced reds in soda-lime glasses. In many other glasses, it reduced the oxide to metallic copper and caused only a slight change in colours. Cuprous oxide. Red glasses were given with $Na_2O.CaO.3SiO_2$ and zinc glasses, whilst the other glasses showed only slight changes in colour, the oxide being generally reduced to metallic globules. Metallic copper. The results obtained with metallic copper and its oxides indicate that arsenious acid tends to reduce the oxides and also to accelerate the growth of copper particles. In glasses coloured by copper salts, the action is chiefly a reducing one, copper globules or red glasses being produced. However, little or no effect was observed in batches containing nitrate or acetate of copper. The effect of stannic oxide on colours produced by copper and its oxides is not the same in different glasses. However, it seems to act as a reducing agent. Of 42 batches containing ·2% of cupric oxide and 0·5-2·0% of stannic oxide, only 6 batches of $Na_2O.CaO$ (or ZnO).$3SiO_2$ and $1{\cdot}3K_2O.ZnO.6SiO_2$ gave red glasses. With regard to the effect of stannic oxide on colours produced by copper salts, the effect of variation in composition of the glasses, and in the type and quantity present of salts on the action of stannic oxide is very strong. The oxide even appears to act sometimes as an oxidising agent. The effect of antimony oxide resembles that of stannic oxide when cupric oxide is concerned. It is very slight for cuprous oxide. Antimony oxide seems to have a stronger effect in changing colours produced by cupric oxide than stannic oxide. It is quite the reverse for cuprous oxide. Antimony oxide tends to produce metallic copper, whilst stannic oxide tends to develop ruby colours. Generally speaking, an addition of a reducing agent (potassium tartrate) together with stannic oxide produces a darker colour than that obtained when one of them is used. With regard to the effect of stannic oxide and arsenious acid on colours produced by cupric oxide, the result of tedious experiments is very complicated. The effect of antimony oxide and potassium tartrate on colours produced by cuprous oxide, was to produce in glasses a suspensoid of metallic copper or a rich deposit of copper globules, indicating a reducing action of antimony oxide and the tartrate. The effect of antimony oxide and arsenious acid on colours produced by cuprous oxide, as brought out by numerous meltings, was very slight. S. KONDO.

ON THE WEATHERING OF BULB GLASS.—Sangoro Takahashi (*J. Jap. Cer. Assoc.*, **32,** 233, 1924). The resistance of two bulb glasses, $0{\cdot}9Na_2O.1{\cdot}1PbO.6SiO_2$ and $1{\cdot}3\ Na_2O.0{\cdot}7CaO.6SiO_2$, to weathering was studied.

The following tables show the results of storing tests :—

TABLE 1. WEATHERING IN A CONCRETE STORE HOUSE.

Methods of storing	After 1 month		After 2 months		After 3 months		Ease of washing off weathered products	
	Lead glass	Lime glass	Lead glass	Lime glass	Lead glass	Lime glass	Lead glass	Lime glass
Packed as usual	Dimmed	Dendritic crystals	Spotted	Dendritic crystals	Snow-like crystals	Dendritic crystals	Very difficult	Fairly difficult
Packed as usual but together with Adsol (Fuller's earth)	None	None	Dimmed	Dendritic crystals	Spotted	Dendritic crystals	Difficult	Easy
Packed as usual after washing with dil. HCl	None	None	None	Granular crystals	Practically none	Granular crystals	Easy	Easy

TABLE 2. WEATHERING OF BULBS, WASHED WITH VARIONS REAGENTS, IN AN APPARATUS SATURATED WITH WATER-VAPOUR AND AT 40°.

Solutions	After a week		After two weeks		Ease of washing weathered products off	
	Lead glass	Lime glass	Lead glass	Lime glass	Lead glass	Lime glass
1/50 *N*. H_2SO_4	None	Dendritic crystals	Somewhat dimmed	Dendritic crystals	Fairly difficult	Fairly difficult
1/500 *N*.HCl	None	Somewhat dimmed	None	Dimmed	Good	Easy
Water (10°C.)	None	Somewhat dimmed	Somewhat dimmed	Dimmed	Fairly difficult	Easy
Water (70°C.)	None	Somewhat dimmed	None	Dimmed	Good	Easy
Unwashed bulb	Spotted	Dendritic crystals	Snow-like crystals	Dendritic crystals	Very difficult	Fairly difficult

TABLE 3.

WEATHERING OF BULB GLASSES CONTAINING SPECIAL INGREDIENTS.

Ingredients	After a week		After two weeks		Ease of washing off weathered products	
	Lead glass	Lime glass	Lead glass	Lime glass	Lead glass	Lime Glass
None	Spotted	Dendritic crystals	Snow-like crystals	Dendritic crystals	Very difficult	Fairly difficult
B_2O_3 3·0%	Somewhat dimmed	Cluster of crystals	Dimmed	Cluster of crystals	Difficult	Easy
Al_2O_3 3·0%	None	Somewhat dimmed	Somewhat dimmed	Minute crystals	Fairly difficult	Easy
TiO_2 1·5%	Somewhat dimmed	Dimmed	dimmed	Dimmed	Fairly difficult	Easy
ZrO_2 1·5%	None	Somewhat dimmed	Somewhat dimmed	Minute crystals	Fairly difficult	Easy
SnO_2 1·5%	None	Fairly dimmed	Fairly dimmed	Granular crystals	Fairly difficult	Easy

The effect of replacing part the soda by potash was also tested.

TABLE 4. WEATHERING OF BULB GLASSES IN WHICH THE SODA WAS PARTIALLY REPLACED BY POTASH.

Per cent. potash in total alkalies	After a week		After two weeks		Ease of washing weathered products off	
	Lead glass	Lime glass	Lead glass	Lime glass	Lead glass	Lime glass
40%	None	Somewhat dimmed	None	Cluster of crystals	Easy	Easy
50%	None	Slight	None	Cluster of crystals	Easy	Easy
70%	None	Slight	Minute crystals	Minute crystals	Easy	Easy
100%	Somewhat dimmed	Spotted	Granular crystals	Thin film	Fairly difficult	Fairly difficult

QUANTITATIVE ANALYSIS OF GLASS.—Jusei Sugie and Otoji Hatayama (The Osaka Industrial Laboratory. *Bulletin* V., No. 3, 22, 1924). Methods of analysing ordinary crown, boro-silicate crown, barium crown, ordinary flint and barium flint are described in detail and the authors propose them as standard methods in this country. S. KONDO.

CONTRIBUTION TO THE CHEMICAL STUDY OF THE GLASSES OF THE MIDDLE AGES.—G. Chesneau (*Verre*, **4**, 176, 1924).

A SHORT HISTORY OF THE GLASS BOTTLE INDUSTRY.—G. E. Alexander (*Glass*, **1**, 4, 1924).

THE HISTORY OF IRELAND'S GLASS INDUSTRY.—(*Glass*, **1**, 15, 1924).

PRACTICAL COSTING FOR GLASS MANUFACTURE.—S. T. Morris (*Glass*, **1**, 19, 1924). A system is described and its advantages are pointed out. Specimen Batch Cost Sheet and Furnace Cost Sheet are shown.

RAW MATERIALS USED IN THE MANUFACTURE OF GLASS.—C. J. Peddle (*Glass*, **1**, 100, 1924). The preparation of good glass sand is described.

NOTES ON THE HARDNESS OF GLASS.—Ad. Lecrenier (*Verre*, **4**, 149, 1924). Calculated according to the Hertz-Auerbach method, the theoretical hardness of crystal glass is twice that of ordinary soda-lime glass, but in reality the contrary is true. A new method of determining hardness is outlined in which the time taken to cut glass to a given depth mechanically is taken as a measure of the degree of hardness. The results show no agreement with those calculated from the Auerbach coefficients. The hardness of glass is shown, however, to vary directly with the coefficients of resistance to tension and compression. The effect of chemical composition is summarised thus: (1) soda glasses are harder than potash glasses containing the same amount of silica; (2) for a given silica content, soda lime glasses increase in hardness with increasing lime and decreasing soda content; (3) boric acid gives great hardness to glass; (4) the addition of soda and lime to lead glasses considerably increases the hardness.

"POLLOPAS,"—AN ORGANIC GLASS.—(*Glashütte*, **54**, 505, 1924). "Pollopas" is a pure, synthetic organic colloid, resembling flint glass in appearance. It is prepared by condensation of carbamide with formaldehyde. A clear, colourless, viscous solution, which is used as a varnish, adhesive, or impregnating medium, is first formed. On heating for a considerable time, this solution is converted into an insoluble, colourless, transparent colloid.

"Pollopas" has the hardness of copper, and can therefore, be turned, etc., on the lathe. Its sp. gr. is about one-half that of glass, whilst as regards elasticity and strength, it is far superior. It has excellent optical properties, and is transparent to ultra-violet rays.

STUDY OF COLOURED GLASSES.—A. Lecrenier (*Verre*, **4**, 104, 1924). A general discussion of the subject.

THE QUESTION OF THE WEEKLY STOPPAGE IN MECHANICAL GLASS-MAKING (FOURCAULT PROCESS).—(*Verre*, **4**, 97, 1924). A report submitted to the Sixth International Labour Conference at Geneva.

FUSED SILICA.—R. Paget (*Nature*, **113**, 748, 1924). A historical sketch is given of the development of the fusion process, followed by an account of the properties of fused silica. The uses to which it is applied are outlined. Two illustrations show the variety of objects into which it can be formed.

COLOUR IMPARTED TO GLASS BY CERIA.—Kitsuzo Fuwa (*J. Jap. Cer. Assoc.*, **32**, 91-93, 1924). Commercial ceria usually contains praseodymium and other rare earth metals. Its brown colour varies with the content of this element. F. used a faint yellow ceria obtained by igniting the purest nitrate obtainable in the country. The chemical formulæ of the glasses were $R'_2O.R''O.3SiO_2$ and $R'_2O.R''O.0{\cdot}5B_2O_3.3SiO_2$, where R′ and R″ represent Na or K and Ca, Mg, Zn, Ba or Pb respectively. Ceria imparts a yellow colour to glass and the influence of its composition on the colour is slight. Strictly speaking, however, a distinct influence is observable, *e.g.*, 2% ceria gave a dark yellow to alkali-lead boro-silicate glasses, while the same amount imparted a slightly yellow colour to alkali-magnesium, zinc or barium silicate glasses. Generally speaking, the yellow is dark in lead glasses, clear and dark in boron glasses and light in ordinary silicate glasses. Sodium-magnesium or zinc boro-silicates have red shades, while potassium-calcium, barium or lead silicate glass tends to show a greenish tint. One per cent. of potassium nitrate added to the batches produced no effect on the coloration given by 2% of ceria. S. KONDO.

PATENTS.

MANUFACTURE OF SPLINTERLESS OR REINFORCED GLASS.—J. Cox (*Brit. Pat.*, 221,552, 8 June, 1923). A sheet of splinterless glass consists of an intermediate sheet of non-inflammable, transparent material, *e.g.*, cellulose acetate, or "celustoid," between two sheets of glass. The inner surfaces of the glass sheets are coated thinly with gum, gum kornifan, or other similar vegetable product, in solution and allowed to dry. The intermediate sheet is treated with tetrachlorethane and acetic acid and then placed between the glass sheets, the whole being subjected to slight pressure at about 40°. The compound glass is sealed to render it waterproof and weatherproof by the application of a suitable cement.

IMPROVEMENTS IN THE MANUFACTURE OF (GLASS) HEAT-INSULATING ARTICLES.—J. H. Delany (*Brit. Pat.* 222,965, 12 July, 1923). In the manufacture of heat-insulating articles formed by the production of a hermetically sealed vacuum in glass, the three separate processes hitherto employed, viz.: blowing, evacuation, and sealing by welding, are eliminated by the use of a condensable gas or vapour under pressure instead of air, in the original blowing operation, the article being then sealed while the glass is still hot. In making thick-walled articles, the gas or vapour in the hollow space between the glass is maintained at a pressure above atmospheric pressure until the space is sealed. On cooling, the vapour or gas condenses, thus producing the desired vacuum. The process is suitable for a variety of purposes, from the production of small heat-insulating containers for food and drink, to the manufacture of bricks and tiles for floors, walls and roofs.

IMPROVEMENTS IN READILY FUSIBLE GLASSES AND ENAMELS.—General Electric Co., for Patent Treuhand Ges. für Elektrische Glüh-

lampen m.b. H. (*Brit. Pat.* 223,837, 16 June, 1924). To ensure firm adhesion and ready fusibility, the softening temperature of glasses and enamels is reduced to 360°-400° by employing the following characteristic molecular composition: PbO 1·0, B_2O_3 0·45-0·55, SiO_2 0·20, Al_2O_3 0·14-0·20, Na_2O 0·04-0·07, K_2O 0·01-0·02, As_2O_3 0·01, Co_2O_2 (or other colouring metallic oxide) 0·04. The glass or enamel is applied either as a dry powder or in paste form, suspended in water. Opacifying media may be fused with the mixture or added during powdering. Sample batches given are: (1) for a blue, transparent glass, softening at 365°—red lead 316 parts by weight, boric acid crystals 88, alumina 6, sodium carbonate 10, potassium nitrate 3, arsenic trioxide 2, and cobalt oxide 3; (2) for a green, opaque glass, softening at 360°—red lead 316, boric acid 86, alumina 6, sodium silico-fluoride 10, potassium nitrate 3, arsenic trioxide 2, and copper oxide 3.

GLASS-ANNEALING FURNACES.—Hartford-Empire Co. for V. Mulholland (*Brit. Pats.*, 220,561-2, 12 Feb., 1924). A tunnel lehr has a roof made vertically adjustable for altering the cross-sectional area of the tunnel. The lehr has a number of sections between the inlet and outlet, each section being formed of a hollow chamber of thin metal packed with insulating material

GLASS BLOWING MACHINE.—United Glass Bottle Manufacturers, F. Sweeting, and C. Hardman (*Brit. Pat.* 221,276, 6 June, 1923). A semi-automatic bottle-making machine is described.

GLASS DRAWING.—E. Danner (*Brit. Pat.* 221,533, 7 May, 1923). Sheet glass is manufactured continuously in a broad, flat stream, which flows over a directing medium to the forming point. The stream is passed through a tempering and controlling zone.

VI.—CEMENT, CONCRETE, MORTARS, ETC.

GERMAN RESEARCH ON HIGH ALUMINA CEMENTS.—C. R. Platzmann (*Rock Prod.*, **27**, No. 19, 1924). Mainly a review of the work of Endell and Schott, whose data and results are tabulated. Ciment fondu reaches a strength of 352 kg. per sq. cm. in 24 hours, but after 28 days it has increased only to 475 kg., which strength is greatly exceeded by many Portland cements. It is, therefore, very important, in estimating the value of alumina cements, to determine whether they weaken with age, making their rapid hardening qualities of little value.

A CONCRETE TOWN.—R. Grün (*Tonind. Ztg.*, **48**, 1,099, 1924). An illustrated description of the Wembley Exhibition, "the first town of concrete."

STUDY ON SOREL'S CEMENT.—Kiyonobu Kishimoto and Shoji Ueki (The Osaka Industrial Laboratory. *Bulletin* V., No. 2, 26, 1924). The paper relates to the manufacture of Sorel's cement with Manchurian magnesite and crude magnesium chloride. The magnesite, calcined for 8 hours at 800°, contained MgO 89·2, CaO 3·5, Al_2O_3 and Fe_2O_3 1·45, SiO_2 3·24 and ignition loss 1·45. Dried crude magnesium chloride was composed of $MgCl_2$ 91·1, alkali chlorides 8·1 and $CaSO_4$ 0·5. The results of calcining the magnesite in pieces about 3 cm. in size, at various temperatures are: (1) Magnesia calcined at 600° or 700° causes contraction in setting, while that calcined at 1,000° or 1,100° expands; (2) the tensile strength of the cement after 1 week is greater than that after 4 weeks when the magnesite has been calcined at 600° or 700°. The relation is reversed when it has been heated at 800° or higher; (3) Moreover, the strongest cement is obtained, when the mineral is calcined at 800° or 900°; (4) Incomplete dissociation of the magnesite sometimes causes crumbling of the briquettes. Experiments with solutions of 1·134 to 1·308 sp. gr. indicated that the stronger the solution, the stronger the cement; generally speaking, an excess of the solution reduces the tensile strength of the cement briquettes. Roughly speaking, the tensile strength of the cement-sand mortar

is inversely proportional to the content of sand. Weathering, or the growth of minute white crystals, and sweating on the surface of the cement products are chiefly due to the presence of free magnesium chloride. These defects can be prevented by dipping the set products in a solution of sodium silicate (1·036–1·18 sp gr.) potassium silicate, hydrogen ammonia fluoride or potassium cyanide. S. KONDO.

UTILIZATION OF WASTE GYPSUM.—Kiyonobu Kishimoto (The Osaka Industrial Laboratory. *Bulletin* V, No. 2, 12, 1924). Plaster of Paris prepared from waste moulds, or other artificial gypsum, is generally useless, since plaster, or moulds made of it, are weak or porous. However, the waste gypsum can be used in the manufacture of Keene's or marble cement. The author has studied the manufacture of Keene's cement from waste moulds and has succeeded in preparing cement equal in quality to that made from natural gypsum, by the following process. The waste gypsum is dehydrated to the soluble anhydrite at 150°–170°, dipped in a 3–5% solution of alum overnight, so as to make the content of anhydrous alum in the finished product lie between 1·5–2·5%, and is then ignited at 700°–800° for an hour. The ignition at too low a temperature makes the product grey and not friable, while too high a temperature reduces its strength. Its setting is accelerated by an increase of alum. Other processes, *e.g.*, one in which the waste moulds were heated at 700° instead of 150°–170° as described above, gave poor results. S, KONDO.

PATENTS.

MANUFACTURE OF ARTIFICIAL STONE OR MARBLE.—W. H. Clegg and G. Whittaker (*Brit. Pat.* 221,857, 16 June, 1923). A mixture of finely divided sulphur and dry siliceous sand free from chalk, lime or other calcium compounds, is heated to about 400° and maintained at this temp. for at least 6 hours with frequent stirring. Finely powdered china clay, or iron or steel slag, may be substituted for siliceous sand. A suitable proportion, *e.g.*, 5 to 25 per cent. of finely divided asbestos fibre, may also be added to the mixture. Articles may be made from the mixture by casting in lubricated non-ferrous moulds ; the casting is removed whilst still warm and its surface treated with a mixture of beeswax or ceresin wax with petroleum or turpentine.

PROCESS OF PRODUCING (ABRASIVE) SUBSTANCES FROM BORON AND CARBON.—Hartstoff-Metall Akt. Ges. (for E. Podszus). (*Brit. Pat.* 204,337, 20 Sept, 1923). The object of the invention is to reduce the brittleness, and increase the hardness of boron carbide. Boron, boron nitride, or boron carbide, or a mixture of these, together with the correct proportion of carbon, are heated to the necessary high temp. Best results are obtained if carbon is added in such quantity as to produce the compound B_3C, *i.e.*, to the extent of 26-27 per cent. The molten mass must be cooled rapidly to prevent decomposition. The carbon may be introduced by subjecting the molten mass to the action of coal smoke at a high temperature. To increase the strength of the material, small quantities of metals having a high melting point, *e.g.*, tungsten, titanium, or the carbides thereof, may be added.

PREPARATION OF CEMENT OR CEMENT MORTARS FROM FUEL RESIDUES.—A Gaertner (*Ger. Pat.* 400,057, 4 Oct., 1922). Powdered coal, together with the other ingredients, is burned in a vertical cylinder, *e.g.*, in the so-called Bettington boiler, the powdered mixture being introduced under pressure at the bottom. No loss of heat occurs, and no trouble is experienced with the residues in the furnace.

PREPARATION OF A CEMENT FROM LIGNITE ASH CONTAINING GYPSUM.—H. Luftschitz (*Ges. Pat.* 400,626, 17 Aug., 1922). Flue ashes, free from carbon, are ground to cement fineness without previous calcination. In a 1 : 3 mortar mixture this binding agent gave a crushing strength of 103 kg. per sq. cm. and a tensile strength of 17·2 kg. per sq. cm. after seven days.

MANUFACTURE OF ARTIFICIAL MARBLE AND LIKE SUBSTANCES.—E. Douzal (*Brit. Pat.* 207,497, 5 July, 1923). A double salt, such as alum, or a mixture of two isomorphous simple salts (potassium and aluminium sulphates) which combine to produce a double salt, or again, a mixture of double salts, isomorphous with one amother (common alum and chrome alum) are melted in their crystallisation water at a temperature below boiling point. Hydrated calcium sulphate in powder form is added to the salts thus melted, the treatment being conducted without the addition of water.

A NEW METHOD OF MANUFACTURING SAND-LIME CONCRETE AND BRICKS, PIPES, ETC.—K. Caccia (*Brit. Pat.* 222,923, 3 July, 1923). Improved sand-lime concrete, cement, etc., for all purposes are obtained by adding a predetermined amount of sulphuric acid to the sand-lime mixture. The product is still further improved by the addition of organic substances, such as tar, which render it anhydrous. The product is much cheaper than ordinary sand-lime mixtures, solidifies quickly, sets very hard and has good internal adhesion.

MANUFACTURE OF FUSED CEMENT AND APPARATUS THEREFOR.—Société Anon. des Chaux et Ciments de Lafarge et du Teil (*Brit. Pat.* 222,426, 9 Nov., 1923). Fused cement, particularly aluminious cement, is manufactured in a reverberatory furnace having in its walls, vertically above the hearth, an opening, through which the raw material is fed continuously. One or more tuyères, through which air is blown, project into the furnace and direct the flames from gaseous, liquid, or pulverised fuel on to the material on the hearth. The fused cement flows away continuously through a weir opening in the furnace wall.

IMPROVED APPARATUS FOR THE MANUFACTURE OF CEMENT BY FUSION.—Société Anon. des Chaux et Ciments de Lafarge et du Teil. (*Brit. Pat.* 222,427, 9 Nov. 1923). Addition to above. The furnace proper is fed continuously by an auxiliary furnace, preferably of the rotary type, which is heated by the hot gases from the reverberatory furnace. Means are provided for regulating the heating of the auxiliary furnace and for feeding raw material to it continuously.

VII.—CHEMICAL AND ANALYTICAL PROCESSES.

PHYSICO-CHEMICAL PHENOMENA IN GLASS-MAKING AND CERAMICS.—A. Granger (*Verre*, **4**, 73, 1924). Evidence is produced to show that glass is not a definite chemical compound, but rather a solid solution (*cf.*, *Note on Coloured Glasses*, Abs., p. 75). The property of plasticity of clays is discussed. The correct application of glazes to ceramic bodies is not so much a problem of adjustment between the two co-efficients of expansion as of the production of a glaze having a wide range of viscosity and greater elasticity.

VIII.—HISTORICAL, EDUCATIONAL INSTITUTIONS, ETC..

SHOULD THE MEANING OF THE WORD "CERAMIC" BE EXTENDED ?.—J. Loebnitz (*Verre*, **4**, 193, 1924). No advantage would be gained, in the French view, by extending the significance of the term "ceramics" to include the lime, plaster, cement, etc., industries.

THE JEAN WURZ-MANNHEIM COLLECTION OF FRANKENTHAL PORCELAIN.—(*Sprech.*, **57**, 643, 1924). Eleven illustrations of porcelain figures are given, representative of XVIII. century Frankenthal porcelain.

RECENT RESEARCH IN CERAMIC HISTORY.—H. Schmitz (*Ker. Rund.*, **32**, 727, 1924). An illustrated review of recent literature.

EDUCATIONAL CURRICULUM FOR CERAMISTS.—H. Auvera (*Ker. Rund.*, **32**, 572, 1924). In addition to the subjects included under a good general education, an efficient course should include lectures on : (1) Ceramic raw materials, occurrence, composition, etc. ; (2) principles of experimental physics, heat theory, etc. ; (3) general engineering and mechanics, electro technique ; (4) building and construction ; (5) works management, organisation, etc.

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